Rio Blanco Oil Shale Project

FINAL ENVIRONMENTAL BASELINE REPORT FOR TRACT C-a AND VICINITY

BOOK 2 OF 2

Gulf Oil Corporation – Standard Oil Company (Indiana)

May, 1977

RIO BLANCO OIL SHALE PROJECT

FINAL ENVIRONMENTAL BASELINE REPORT FOR TRACT C-a AND VICINITY

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FOREWORD

Information presented herein represents the summation two-years of extensive environmental baseline studies for Tract C-a oil shale tract in northwestern Colorado. This report is supported by a large number of previously submitted documents, including ten quarterly progress reports and two annual summaries. All of these documents are on file with the Area Oil Shale Supervisor in Grand Junction, Colorado and can be examined upon request.

Exploratory activities and baseline studies were conducted in accordance with the "Tract C-a Oil Shale Lease and Environmental Stipulations" as issued by the United States Department of Interior on February 5, 1974 and as amended by subsequent "Conditions of Approval". Immediately following award of the lease, Gulf Oil Corporation and Standard Oil Company (Indiana) submitted a "Preliminary Development Plan" which described planning objectives of the two companies for the development of Tract C-a.

This was followed in May 1974 by an "Exploratory Plan" as required by Section 10d of the lease. This document detailed the plans of Gulf and Standard for obtaining environmental baseline data, establishing monitoring plans, and aquiring geotechnical data for input into mining, processing, and environmental protection design.

Detailed descriptions of objectives, methods, and scheduling of environmental baseline studies were prepared by each individual contractor and submitted late in 1974 as scopes-of-work. These scopes-of-work for each discipline area, as amended and agreed to by the Area Oil Shale Supervisor are on file in the Grand Junction Office.

Data collected during the baseline period were submitted each quarter in conjunction with descriptive information on trends and conclusions observed during the period. RBOSP Progress Reports 1 through 10 and accompanying summary volumes are also on file in Grand Junction. Persons interested in examining data sets from which conclusions for the final report were drawn are referred to these reports.

Following the first year of baseline studies, trends and conclusions for terrestrial and aquatic ecological studies were presented as annual reports. These reports, dated March 1976, also present complete descriptions of program objectives and data accumulation methods. Persons interested in the application of technical methods on Tract C-a should consult these two reports.

Cultural resource surveys in the study area are described in RBOSP quarterly progress reports. A comprehensive report on the cultural resources of the area, submitted in October 1976, is also on file with the Area Oil Shale Supervisor.

Analysis of two years baseline data for the preparation of the final report resulted in the generation of many pages of support documentation. Over 3,000 pages of documentation were generated for hydrology studies alone. This documentation, consisting of computer runs and descriptions of statistical analyses, is presented in RBOSP Progress Report 10.

In addition, the in-depth interpretation, supporting analyses, and graphical representations of terrestrial baseline data are presented in RBOSP Progress Report 10. Other materials presented in Progress Report 10 include support material for aquatic studies and sediment studies, and atmospheric data.

The tenth progress report also contains the cause-effect, measurability, and interactions matrices generated for the purposes of identifying impacts of proposed tract development on the environment, selecting monitoring parameters, and identifying important physical and biological interactions for the study area. These matrices are accompanied by descriptive text materials.

Maintenance of clarity and brevity of the Final Environmental Baseline Report required omission of a great deal of specific information. Some readers may object to this approach when they fail to find items of special interest to them. However, we feel that the approach taken herein was the only feasible means of satisfactorily representing the massive amount of information gained through the study efforts.

INTRODUCTION

This final environmental baseline report presents a description of the environment and wildlife on and near oil shale lease Tract C-a prior to commencement of oil shale development operations. Tract C-a is one of two prototype oil shale lease development areas in northwestern Colorado. Proposed development areas (as well as two in Utah) are located on public land managed by the Bureau of Land Management (BLM), United States Department of Interior (USDI).

The Tract C-a project, better known as the Rio Blanco Oil Shale Project (RBOSP) is the outgrowth of a Department of Interior decision to encourage the development of oil shale reserves on public land in the west by placing selected reserves on public auction as prototype development areas. Lease sales were preceded by informational core drilling by interested private firms to determine the extent of the resources in the area. Once drilling was complete, the USDI offered six tracts (two in Colorado, two in Utah and two in Wyoming) for lease. Tract C-a was placed on auction first. Gulf Oil Corporation and Standard Oil Company (Indiana) jointly offered the highest bid for Tract C-a in January 1974.

Development of Tract C-a is strictly regulated by the terms of the oil shale lease (Serial No. C-20046) issued to Gulf and Standard in February 1974 by the BLM. The environmental stipulation of this lease required the lessee (Gulf and Standard) to conduct a two-year integrated environmental baseline study of the total ecology of Tract C-a to provide an understanding of the basic ecological interrelationships important for successful environmental protection and to allow identification of ecological parameters important for monitoring.

In compliance with this stipulation, Gulf and Standard (RBOSP) engaged the services of Limnetics, Incorporated, of Milwaukee, Wisconsin to manage their environmental programs. RBOSP subsequently engaged the services of EG & G Corporation, Waltham, Massachusetts to conduct meteorology studies. Ecology Consultants, Inc., Ft Collins, Colorado to conduct terrestrial studies, NUS Corporation, Denver, Colorado to conduct aquatic studies and Dr. Alan Olson, University of Denver to conduct cultural resource studies. Later Mr. Steven Baker, Montrose, Colorado, and Dr. Paul O. McGrew, University of

Wyoming were brought in to assess historic and paleontologic resources of the area. Wright Water Engineers, Denver, Colorado was engaged to conduct hydrology studies and the Colorado School of Mines conducted soils studies.

Terrestrial hydrology and aquatic baseline studies were initiated in October 1974. Air studies began in February 1975. Cultural resource studies were conducted during 1975 and 1976.

On September 1, 1976, Gulf and Standard suspended their operations on Tract C-a, with the exception of environmental studies, which were continued through completion. The suspension period is effective until September 1, 1977. During this suspension period, RBOSP engaged NUS Corporation to conduct interim monitoring studies and to complete a detailed analyses of baseline environmental data. These analyses were conducted in order to identify with greater resolution, the ecology of the study area. The results of these analyses and original baseline interpretations are presented in this final report on the environment of Tract C-a and vicinity.

The report contains six sections as follows:

- Section I - Climate and Air Quality
- Section II - Aquatic Resources
- Section III - Terrestrial Ecology
- Section IV - Physical and Biological Interactions
- Section V - Cultural Resources
- Section VI - Revegetation

Each section contains several chapters which present the baseline results by discipline area. Appendices containing the data analysis support material are too lengthy to present here. Therefore, these materials have been submitted in RBOSP Progress 10, May 1977. In addition, the base report for the terrestrial ecological studies for Tract C-a is presented in its entirety with accompanying maps in RBOSP Progress Report 10. Information on the contents of the base report is provided as an appendix to this report for the reader's information.

SEC. 3

SECTION 3

TERRESTRIAL ECOLOGY

SECTION III - TERRESTRIAL ECOLOGY

PREFACE

This final report briefly summarizes results and interpretations from an intensive two-year study of terrestrial ecosystems on and surrounding oil shale Tract C-a in the Piceance Creek basin of northwestern Colorado. The complex and varied nature of terrestrial ecological studies made it impossible to present results of these studies in as much detail as other disciplines (e.g., hydrology, air quality) within the limited space of this report. Therefore, results of baseline data analysis and in-depth interpretations of these analyses are presented as a base document in RBOSP Progress Report 10 (1977). Those individuals desiring additional information on terrestrial studies can obtain this information from the Area Oil Shale Supervisor in Grand Junction, Colorado. Information on the contents of the base document is provided in the appendix to this report.

The overall objective of this terrestrial ecology program was to study and define the baseline conditions of Tract C-a and vicinity terrestrial ecosystems as required by the Oil Shale Lease Environmental Stipulations (Federal Register, Volume 38, Number 230, Part 3). The standarized methodologies rigorously implemented during the two-year assisted in the development of the terrestrial baseline norm described in this final report. This baseline norm will provide the foundation upon which meaningful terrestrial ecological monitoring programs will be developed. Data collected during monitoring programs implemented subsequent to startup of mining and retorting operations will be quantitatively compared against this baseline norm in attempts to identify and mitigate whatever adverse terrestrial ecological perturbations result from oil shale development.

Terrestrial ecosystems in the study area (Tract C-a and all areas within five miles of Tract C-a's borders) were analyzed with respect to species composition, abundance of individuals, species diversity, seasonal variation in composition, abundance and diversity, and terrestrial ecological interrelationships.

Specific terrestrial ecological components studied included soils, vegetation, small mammals, large mammals, mammalian predators, reptiles and amphibians, gamebirds, songbirds, raptorial birds, domestic livestock, and terrestrial invertebrates. An investigation of the existing use and condition of range land vegetation was also conducted.

Intra-disciplinary interactions have been identified on an interactions matrix which appears in RBOSP Progress Report 10 (1977). A discussion of these interactions is presented in Section IV of this report.

CHAPTER 1 - SOILS AND TRACE METALS

ABSTRACT

The depth of soil to bedrock on tract was quite variable. Average depth ranged from 3 m (10 feet) on the slope to 7.5 m (25 feet) in the valley bottoms. These soils were composed of a mixture of sandy silt, sandy clay, and gravelly clay. Surface and subsurface soils were slightly basic (average pH of 8.3 and 8.4). Organic matter content of these soils was moderate to low in surface (3.1 percent) and subsurface (1.9 percent) soils, with maximum levels of organic matter at the soil surface. Cation exchange capacity for soils of this semi-arid region was normal, with the cation exchange capacity of surface soils (CEC=34.2) higher than subsurface soils (CEC=22.7). There were essentially no chemical differences between surface and subsurface soils on tract. Both surface and subsurface soils were sufficiently deficient in nitrogen and phosphorus to recommend their application in reclamation programs. Only traces of potentially toxic elements occurred in surface and subsurface soils of Tract C-a and vicinity. Trace element concentrations were within ranges considered normal for soils and nontoxic to plants and animals. Selenium is the only exception, with three sites outside the boundaries of the tract containing more plant-available selenium than is normally found in soils of semi-arid regions. Most soils of the study area had a coarse to medium texture and had the potential to retain sufficient water and nutrients for normal plant growth. Soil material suitable for top dressing in reclaimed areas varied in depth from less than 0.5 m to over 1.5 m. Rock is the primary factor limiting use of certain soils for reclamation. Although most soils in the study area, with the exception of soils of the Rock Outcrop-Torriorthent complex, appeared to have some surface soil suitable for top dressing material (topsoil), the Glendive series appeared to have the best balance of nutrients and the greatest depth of suitable soil material.

Surface and subsurface soils in the study area were studied to provide the following information:

- To document chemical and physical characteristics of soils of Tract C-a prior to disturbance for shale oil production,
- To provide information required for designing efficient and effective revegetation programs through (1) identifying depths of available and useful top dressing soil material, (2) identifying saline, sodic, or potentially toxic soils, (3) documenting the level of available nutrients for plant growth, and (4) identifying water-holding capacity of soils,
- To provide further understanding of the interaction of plants and soil through identifying the influence of plants on soil properties, and
- To fulfill requirements of the oil shale lease.

SOILS OF TRACT C-a AND VICINITY

This chapter is divided into three sections. Soil properties of Tract C-a, based on 47 sampling sites for surface soils (130 samples), and four drill-hole sampling sites for subsurface soils (20 samples), are discussed in the first section. The next section considers the traits of the entire study area including Tract C-a, 84 Mesa, and surrounding areas. This section summarizes data from 107 sampling sites (312 samples). Soil traits as influenced by vegetation are discussed in the last section.

A detailed discussion of methods and results of the soil sampling program may be found in RBOSP Progress Report 9 1977, for surface soils and RBOSP Progress Report 7 1976, for subsurface soils.

I. SOILS OF TRACT C-a

Documenting existing environmental conditions of Tract C-a was a primary concern addressed by the RBOSP environmental baseline studies of Tract C-a and vicinity. In order to more effectively present results of the soil studies, information on the tract will be presented first, followed by information on the study area (Tract C-a and vicinity) as a whole. A limited amount of additional information on general physical and chemical characteristics of soils and overburden of the oil shale area may be found in reports prepared by Campbell et al. (1974), Fox (1974), and Ringrose et al. (1976).

Soils and overburden were arbitrarily separated into two classes for study and analytical purposes. These classes were surface soil (material in upper 1.5 m (5 feet), and subsurface soils and overburden (material below 1.5 m to bedrock or to a maximum depth of 15.25 m (50 feet). The

depth of soil to bedrock on tract was quite variable and averaged 3 m (10 feet) on the slopes to 7.5 m (25 feet) in the valley bottoms. Some of the flat tops of hills and ridges had soil depths as shallow as 0.3 m (1 foot or less. A detailed discussion of the chemical and physical properties of soils of Tract C-a and vicinity has been presented in previous RBOSP reports (surface soils, Progress Report 9; subsurface soils, Progress Report 7).

The following discussion considers general soil properties of Tract C-a. Mean, range, and standard deviation of each parameter are presented in Table 3.1 for surface soils and Table 3.2 for subsurface soils. The range and standard deviation demonstrate considerable variation within most parameters measured. This variation was expected, due to the high degree of natural variation between soil types sampled and soil depths.

A. pH

Plants and soil microorganisms respond strongly to their chemical environment; soil reaction (or pH) is an important chemical trait of soils. This trait is particularly important to plants because it influences the nutrients available for plant absorption and the concentration of toxic ions. In general, soil is acid where precipitation is high enough to leach appreciable amounts of exchangeable bases from the soil and soil is alkaline where precipitation is generally insufficient to leach the exchangeable bases (especially calcium, sodium, and magnesium) from the soil.

The pH values (in water) for soils on tract ranged from neutral (7.3) to highly alkaline (9.8) for surface soils and from 8.0 to 9.0 for subsurface soils. The alkaline nature of almost all of the soils in the study area was expected and is typical of areas with low rainfall. A small percentage of the soil samples had pH values greater than 8.9. These high pH values indicated that the sample contained alkali salts which often interfere with plant growth. Areas of alkali salt concentrations are discussed in the section on exchangeable sodium percentage.

TABLE 3.1

CHEMICAL AND PHYSICAL TRAITS OF SURFACE SOILS OF TRACT C-a(1)

Parameter	pH in Water	pH in 0.01M $CaCl_2$	Soluble Salt Electrical Conductivity mmhos/cm (2)	Soluble Salt Electrical Conductivity mmhos/cm (3)	Sodium Water Soluble (milliequivalents/100 g)	Sodium NH_4 Acetate Soluble (milliequivalents/100 g)	Cation Exchange Capacity (milliequivalents/100 g)	Exchangeable Sodium Percentage
Mean	8.3	7.9	0.86	3.2	1.09	2.82	34.2	5.1
Range	7.3-9.8	6.9-9.2	0.18-11.50	0.6-59.0	0.07-19.48	0.25-30.1	15.4-63.8	0.1-53.5
Standard Deviation	0.5	0.4	1.40	6.2	2.5	4.1	10.5	9.5

Parameter	Ammonium ppm	Nitrate ppm	Phosphorus $NaHCO_3$ Extractable ppm	Potassium Available ppm	Water Soluble Magnesium ppm	Water Soluble Calcium ppm	Water Soluble Potassium ppm	Water Soluble Sulfate ppm	Water Soluble Boron ppm	DTPA Extractable Copper ppm	DTPA Extractable Manganese ppm	DTPA Extractable Iron ppm	DTPA Extractable Zinc ppm
Mean	9.0	10.5	12.6	262.1	14.5	59.6	10.0	302.8	0.7	2.1	30.2	81.0	1.4
Range	0.4-27.9	<0.1-420.0	1.0-125.0	80.0-1190.0	0.4-319.7	3.6-679.0	1.1-83.5	5.0-4158.0	0.5-1.9	0.5-13.6	6.0-120.0	12.0-210.0	0.4-4.3
Standard Deviation	5.3	43.2	13.1	202.0	33.0	105.7	13.8	624.0	0.2	1.6	20.9	46.4	0.7

Parameter	Molybdenum Anion Exchangeable ppm	Organic Matter %	Gypsum Requirement MEQ/100 g	Lime Requirement lb $CaCO_3$/acre	Total Phosphorus ppm	Total Arsenic ppm	Total Cadmium ppm	Total Chloride ppm	Total Chromium ppm	Total Cobalt ppm	Total Fluoride ppm	Total Mercury ppb
Mean	0.3	3.1	0.3	0	450.1	10.0	0.5	1001.8	44.0	7.0	596.5	24.0
Range	0.1-1.3	0.1-16.8	0.2-2.2	0	201.0-840.0	5.0-40.0	<0.5-0.5	400.0-2500.0	20.0-65.0	1.0-35.0	290.0-1150	10-110
Standard Deviation	0.2	2.2	0.4	0	135.9	7.2	<0.01	338.1	10.0	3.2	188.7	15.1

Parameter	Total Antimony ppm	Total Vanadium ppm	Selenium Available ppb	NH_4 Acetate Extractable Nickel ppm	NH_4 Acetate Extractable Lead ppm	Background Radioactivity Uranium ppm	Background Radioactivity Equivalent Uranium ppm	Background Radioactivity Equivalent Thorium ppm	Background Radioactivity Potassium Radioactivity %	Background Radioactivity Radium-226 Picocuries/g
Mean	1.0	57.7	34.1	0.7	1.6	2.3	2.9	9.4	2.4	1.0
Range	1.0-3.0	30.0-110.0	10-500	0.3-2.4	0.7-4.0	<2.0-5.0	1.0-8.0	3.0-17.0	0.5-2.5	0.5-2.5
Standard Deviation	0.3	13.6	60.3	0.4	0.5	0.7	1.2	3.3	0.6	0.4

Parameter	Bulk Density g/cm³ (4)	Water-Holding Capacity, % (Dry Sample Wt. Basis) 1/3 Bar Suction	Water-Holding Capacity, % (Dry Sample Wt. Basis) 15 Bar Suction	Particle-Size Analysis, Wt. % Sand -2.0 +0.05 mm	Particle-Size Analysis, Wt. % Silt -0.05 +0.002 mm	Particle-Size Analysis, Wt. % Clay -0.002 mm	Textural Class
Mean	1.22	26.9	13.0	36.5	50.3	13.2	Loam
Range	0.93-1.25	14.9-50.9	7.0-22.9	7.0-73.0	22.0-77.0	2.5-25.0	
Standard Deviation	-	6.9	3.3	15.6	12.7	5.1	

(1) n= 130.
(2) Sample to extract ratio: 1 to 2.
(3) Conductivity for a saturation extract based on 1 to 2 ratio conductivity data and the 1/3 bar water-holding capacity.
(4) Weighted average of bulk density of the eight soil series found on Tract C-a.

TABLE 3.2

CHEMICAL AND PHYSICAL TRAITS OF SUBSURFACE SOILS OF TRACT C-a(1)

Parameter	pH in Water	pH in 0.01M $CaCl_2$	Soluble Salt Electrical Conductivity mmhos/cm (2)	Sodium Water Soluble (milliequivalents/100 g)	Sodium NH_4 Acetate Capacity (milliequivalents/100 g)	Cation Exchange CapacitySodiu (milliequivalents/100 g)	Exchangeable Sodium Percentage
Mean	8.4	8.2	1.49	1.55	3.33	22.7	7.8
Range	8.0-9.0	7.8-8.8	0.23-8.40	0.07-8.30	0.49-19.3	16.4-33.4	1.2-46.0
Standard Deviation	-	-	2.36	2.50	3.87	3.3	5.7

Parameter	Ammonium ppm	Nitrate ppm	Phosphorus $NaHCO_3$ Extractable ppm	Potassium Available ppm	Water Soluble Magnesium ppm	Water Soluble Calcium ppm	Water Soluble Potassium ppm	Water Soluble Sulfate ppm	Water Soluble Boron ppm	OTPA Extractable Copper ppm	OTPA Extractable Manganese ppm	OTPA Extractable Iron ppm	OTPA Extractable Zinc ppm
Mean	26	8.5	10	167	90	120	21	984	<0.8	2.8	28	122	1.2
Range	13-35	0.4-27.7	3-24	80-930	11-567	17-915	4-130	30-6362	<0.5-2.3	0.8-4.7	14-64	38-204	0.3-2.0
Standard Deviation	6	5.7	3	48	156	205	15	1882	0.5	.8	10	32	0.3

Parameter	Molybdenum Anion Exchangeable ppm	Organic Matter %	Gypsum Requirement MEQ/100 g	Lime Requirement lb $CaCO_3$/acre	Total Phosphorus ppm	Total Arsenic ppm	Total Cadmium ppm	Total Chloride ppm	Total Chromium ppm	Total Cobalt ppm	Total Fluoride ppm	Total Mercury ppb
Mean	<0.30	1.9	0	0	673	8	<0.5	2000	40	6	374	28
Range	<0.01-0.80	0.4-5.3	0	0	421-896	3-14	-	1000-3500	35-50	4-8	30-580	14-55
Standard Deviation	0.22	0.7	0	0	82	2	-	500	4	1	99	9

Parameter	Total Antimony ppm	Total Vanadium ppm	Selenium Available ppb	NH_4 Acetate Extractable Nickel ppm	NH_4 Acetate Extractable Lead ppm	Background Radioactivity Uranium ppm	Background Radioactivity Equivalent Uranium ppm	Background Radioactivity Equivalent Thorium ppm	Background Radioactivity Potassium Radioactivity %	Background Radioactivity Radium^{226} Picocuries/g
Mean	<1	59	35	0.9	0.4	4	3	9	2.5	1.3
Range	<1-1	47-143	10-150	0.7-1.3	0.1-0.6	2-6	2-5	4-14	2.1-3.0	0.5-1.5
Standard Deviation	-	10	42	0.2	0.1	1	1	2	0.2	0.3

(1) n = 20
(2) Sample to extract ration: 1 to 2.

Soil pH increased as depth increased, a trait common to many soils. As organic matter decomposes, various acids are produced and released to the soil. Decomposition is most intense in surface soil and decreases sharply with increasing depth. In addition, leaching removes carbonates from the surface and deposits them lower in the soil profile. Such processes develop gradients in soil pH.

Values of pH determined in a calcium chloride solution are about 0.5 pH units below pH determined in water (Peech 1965). The pH values in calcium chloride ranged from 6.9 to 9.2 and averaged 7.9 for surface soils, and 7.8 to 8.8 and averaged 8.2 for subsurface soils. These values are considered typical for semi-arid parts of the west. Over 50 percent of the samples taken in the study area had a pH value between the narrow range of 8.0 and 8.6.

B. Soluble Salt Electrical Conductivity

Concentration of dissolved salts in soil was measured by electrical conductivity of soil solution. When conductivity of such a solution exceeds 4.0 mmhos/cm, the soil is classified as saline (Richards 1954). Saline soils can contain sufficient concentrations of soluble salts to restrict growth of many plant species. However, plant response to saline conditions is species dependent (Hayward and Wadleigh 1949; Richards 1954).

Two measurements of soluble salt electrical conductivity were made on each soil sample. One measurement was made on the water extract obtained when one part of soil was mixed with two parts of water. The second measurement of conductivity adjusted the former value to reflect the concentration of soluble salts in a soil saturated with water. This second parameter has been correlated with plant growth and is the basis of the following discussion.

Electrical conductivity of surface soils of the tract ranged from less than 1.0 mmhos/cm to a high of 59 mmhos/cm. When electrical conductivity exceeds approximately 15.0 mmhos/cm, few plant species can

survive, and those that are able to grow may be restricted in their yield (Barth 1976). The few highly saline zones identified on tract occur between the 50-150 cm depth and shallower intervals were either nonsaline or slightly saline. The general absence of highly saline material at or near the surface apparently mitigated detrimental effects of salts on plant growth since the few sites where highly saline subsurface intervals occur support vegetation similar to areas lacking saline zones. When a highly saline interval is at or near the surface, plant species composition reflects the presence of the salt. These sites are generally dominated by shadscale or basin wild-rye. Both species appear to be salt tolerant.

Electrical conductivity increased from 2.2 mmhos/cm at the soil surface to 7.7 mmhos/cm at the 100-150 cm depth. This increase in salinity with depth was due, in part, to the leaching of water soluble salts from surface to subsurface. Other factors may also be involved. In many sections of the study area, aeolian material has been deposited on the original surface. This aeolian material may have contained less soluble salts than the original surface. Thus, surface and near surface soils are apparently of one geologic origin while the deeper soils are of another geologic origin.

Mean electrical conductivity of subsurface soils (1.49 mmhos) was slightly higher than for surface soils (0.86 mmhos), but was well within the tolerance range for most plants typically found in the vicinity of tract.

C. Cation Exchange Capacity

Cation exchange capacity is the sum total of exchangeable cations that a soil can absorb (Brady 1974). Clay minerals and humus account for essentially all of a soil's exchange capacity. When average cation exchange capacity of the study area was related to the percentage clay, the exchange capacity was approximately 250 meq/100 g. This relatively high exchange capacity indicated that montmorillonite was the dominant

clay mineral. Montmorillonite is the clay mineral most commonly found in semi-arid regions. There was little difference between cation exchange capacity of surface and subsurface soils.

D. Exchangeable Sodium Percentage

Exchangeable sodium percentage (ESP) expresses the percentage of sodium ions on the soil exchange complex. When this percentage exceeds 15.0, the soil is termed sodic (or alkali) (Lunt 1966). A given level of ESP is more detrimental to plant growth in a soil with a high percentage clay than with a low percentage clay. This is due to the greater degree of particle dispersion in a clayey soil than in a sandy soil (Pearson and Bernstein 1958; Pearson 1960). Water penetration into a dispersed soil is very slow, thus increasing erosion potential and reducing the amount of soil water available for plant use.

Mean ESP for surface soils of tract was 5.1 and ranged from less than one to 53 (Table 3.1). Sodic intervals in the soil occurred in several areas and 13 percent of the surface soil samples collected on tract were sodic. In only two of the 17 samples did a sodic layer occur in the 0-10 cm or 10-50 cm interval. The sodic condition was not generally found at depths shallower than 50 cm. Considering that the ESP of subsurface soils was not much higher than surface soils and the sodic soils were either a loam or sandy loam containing less than 15 percent clay, thereby increasing water infiltration, the presence of a sodic horizon below the surface was probably indicative of a deposition of salts in solution to the maximum wetting front depth. Sodium that may have been in or near the surface probably leached out or was replaced by other salts. Therefore, the ESP was not as restrictive to plant growth and water infiltration as might be inferred from the numerical value.

The three components of ESP, water soluble sodium, ammonium acetate soluble sodium, and cation exchange capacity, displayed strong depth functions and as a result ESP increased with depth. Leaching alkali salts and acidification by organic matter plus differences in parent

material within a given sampling location were important factors in establishing this spatial pattern. Subsurface sodic intervals appeared to have little effect on vegetation. Pinyon-juniper or sagebrush dominated most sites where sodic intervals were found. Vegetation on these sites appeared to be similar to vegetation found on sites where sodic intervals were not present. Dominant vegetation in areas where sodic intervals were at or near the surface was greasewood or shadscale.

Sodic soils can be converted to a nonsodic status through the application of various chemical amendments. These amendments, directly or indirectly, add water soluble calcium to the soil. This calcium then replaces sodium held on the exchange complex. The soil is then leached to remove the sodium which is now in a water soluble form. Of the various amendments available, gypsum is most common and least expensive (Barth 1976).

E. Plant Macronutrients

Of the elements necessary for normal plant growth, nitrogen, phosphorus, potassium, magnesium, calcium, and sulfur are required in relatively large quantities. These elements are referred to as macronutrients.

1. Nitrogen

There are three major forms of soil nitrogen: (1) organic nitrogen associated with soil humus, (2) ammonium nitrogen associated with clay minerals (also termed exchangeable nitrogen), and (3) soluble nitrate compounds (Brady 1974). Most soil nitrogen is in organic form and is slowly released through microbial action as ammonium and nitrate. Positively charged ammonium is attracted and held by negatively charged clay minerals. In contrast, nitrate has a negative charge and, consequently, is highly mobile in soil. Plants are able to absorb both ammonium and nitrate forms of nitrogen. However, in most cases ammonium is converted to nitrate prior to plant absorption. This nitrification process requires nitrifying bacteria, a carbon source, oxygen, water, and favorable ambient temperatures.

Nitrogen level in soils used for crop production is commonly kept at approximately 50 ppm (about 80 lbs per acre). Soils in the study area, as in most other natural systems, contained substantially less nitrogen than is advised for agricultural soils. The concentration of nitrate plus ammonium averaged 19.5 ppm (approximately 9.4 ppm elemental N or 16 lbs/A) in surface soils. While this amount of nitrogen was low from a crop production standpoint, it appeared adequate for natural systems. Plants on tract are not visually suffering from a deficiency in nitrogen, although plant growth might increase if nitrogen were applied to the soil.

In some locations there were unusually high concentrations of nitrate. With only one exception, the high levels of nitrate occurred below the soil surface. Several sites have been burned within the last 10 years, as evidenced by charred sagebrush stumps in the area. An increase in soil nitrate is often noted following burning. Delwiche (1956) stated that the common association of high nitrate levels with arid soils is probably not a result of more active nitrification in such soils, but is related to the general accumulation of salts resulting from evaporation of water. Whatever the cause, this subsurface accumulation of nitrate in some sections of the study area appeared to have little, if any, effect on plant growth or species composition.

Both forms of nitrogen show vertical patterns, although the direction is different. Ammonium is highest at the surface and consistently decreases with depth. Soil ammonium is derived almost entirely from decomposition of organic matter. Both organic matter and microbial activity are centered in the surface few centimeters of soils in semi-arid regions (Charley and Cowing 1968). The positively charged ammonium ion is generally held by clay particles and is not subject to translocation by water. Therefore, the concentration of ammonium is highest at the soil surface. Nitrifying bacteria convert ammonium to nitrate. This nitrate is either absorbed by plants and soil microorganisms or it is leached from the surface soil (Delwiche 1970). Thus the concentration of soil nitrate is generally low and subject to loss by leaching. Patterns of vertical

distribution of nitrate in the soil are complicated by the high mobility of the nitrate.

2. Phosphorus

With the possible exception of nitrogen, no other element is as critical in plant growth as phosphorus. The lack of sufficient amounts of plant-available phosphorus curtails many physiological processes and also prevents plants from obtaining other nutrients. Phosphorus deficiency is probably the most critical mineral deficiency in grazing livestock (Allaway 1975). As with most other plant nutrients, phosphorus is supplied by mineral elements in soil and by organic plant residues. Extractable (or plant available) phosphorus on tract ranged from 1 ppm to 125 ppm and averaged 12.6 ppm for surface soils and 10 ppm for subsurface soils. Plants normally do not suffer from phosphorus deficiency until the extractable level falls well below 10 ppm. Few surface soil samples from tract contained less than 10 ppm of extractable phosphorus. Surface soils receive a substantial amount of phosphorus from plant residue while subsoil phosphorus is derived primarily from minerals.

Plant available phosphorus is substantially higher in near-surface soils than in the subsurface soils. Organic matter and soil microorganisms, both of which are concentrated at the soil surface, significantly increase the concentration of available phosphorus (Brady 1974). As organic matter and the population of microorganisms decreases with depth, available phosphorus also decreases.

Total phosphorus values ranged from 95 to 1549 ppm and averaged 450 and 673 ppm for surface and subsurface soils. Shacklette et al. (1971b) found that total phosphorus in soils averages 420 ppm and ranges from 20 to 6,000 ppm. Black (1968) cites 620 ppm as average phosphorus concentration in soils. Total phosphorus in the tract area was within the range cited in the literature as being normal for soils. Most of the total phosphorus present in soils is unavailable to plants (Brady 1974) and the measurement of total phosphorus gives no real indication of plant response to this nutrient.

3. Potassium

Most potassium in soil is held as part of the primary minerals or is fixed in forms that at best are only moderately available to plants. Potassium found in soil solution and on exchange sites is available for plant absorption. This form of potassium averaged 262 ppm for surface soils and 167 ppm for subsurface soils. Plants require approximately 150 ppm of available potassium for normal growth. Intervals with less than 150 ppm of potassium were essentially confined to the subsoil and had no noticeable influence on plant growth, but if subsurface soils are used for reclamation of surface lands then supplemental fertilization with potassium may be necessary.

4. Macronutrients Measured in Water Soluble Forms

Magnesium, calcium, potassium, sulfate, and sodium were measured in a water extract. With the exception of sulfate, these elements also exist in an exchangeable form and the water soluble concentration may be only a small fraction of the total amount available to plants. These nutrients are rarely deficient in semi-arid environments. More commonly, they are present in excessive amounts as salts and limit the ability of plants to absorb water. This salinity aspect has previously been discussed.

As an integral part of the chlorophyll molecule, magnesium is essential to all green plants. This element is also essential to animals. Water soluble magnesium in surface soils averaged 14.5 ppm and ranged from 0.4 to 319.7 ppm. These values appear typical of semi-arid areas and suggest that the magnesium level was sufficient for both plants and animals.

Water soluble potassium averaged 10 ppm for surface soils. This was only 4 percent of the available potassium, with most of the plant-available potassium apparently on exchange sites of clay minerals and soil humus. Vertical distribution of potassium was irregular and the slight accumulation of this element at the soil surface may be related to the release

of potassium through organic matter decomposition. A similar irregular distribution of water soluble potassium was also noted by Presant (1971).

Since soils of semi-arid regions are frequently rich in calcium, calcium deficiencies in plants or animals are rare. Water soluble calcium of surface soils averaged 59.6 ppm. It is probable that substantially more calcium existed on the soil exchange complex.

Sodium is required for the normal growth of some plants, such as Atriplex vesicaria (Brownell and Wood 1956), but it is not a universal plant nutrient. Water soluble concentrations of sodium in the surface soils of tract were ample to meet the requirements of those species requiring sodium. Sodium more often limits plant growth through its contribution to soil salinity.

Sulfur is used in the formation of many proteins and as such is essential for both plants and animals. Only a small percentage of the intervals tested in the study area contained less than 10 ppm sulfate. Soils are not considered sulfur deficient until the level of sulfate is less than approximately 10 ppm.

Water soluble magnesium, calcium, and sulfate displayed a slight increase in concentration as soil depth increased. However, the differences were not statistically significant. As leaching continues to translocate these water soluble constituents, differences may become more striking. Concentrations of these elements were higher in subsurface soils (Table 3.2) of Tract C-a than surface soils (Table 3.1). Apparently these were elemental components of the parent material and were released through weathering of soil and parent materials. Concentration of these elements was not sufficiently high to present a problem of reclaiming subsurface soils brought to the surface since the water soluble forms are easily leached from the surface of soils.

F. Plant Micronutrients

Elements which are needed in relatively small amounts by plants are termed micronutrients and include boron, molybdenum, copper, iron, zinc, chloride, and manganese. For unhindered plant development, these micronutrients must be present in amounts sufficient to meet plant demands, they must occur in proper balance, and cannot be concentrated in amounts which would be toxic to the plants.

Of the seven micronutrients analyzed, only manganese, zinc, and chloride display significant changes with depth. Substantially higher concentrations of manganese and zinc at the soil surface as compared to the subsoil indicated that these elements were associated with organic matter wherever they were probably held as chelated complexes. A general decrease in the concentration of manganese and zinc with depth was also found by Swaine (1955) and Presant (1971). The increase in chloride with depth paralleled that of electrical conductivity. The negatively charged chloride ion is necessary to balance the positively charged ions which electrical conductivity measures.

The content of these micronutrients (except chloride) (Table 3.3) was measured in sagebrush leaves collected from plants occurring on the various soil series on Tract C-a. Tissue analysis data will provide baseline information regarding normal levels of micronutrients in sagebrush leaves on Tract C-a. These present levels are assumed to be non-toxic to the plant.

1. Boron

Boron is essential for plant growth, but the amount required is small and if exceeded is phytotoxic (toxic to plants). Plants vary considerably in their boron requirements and in their tolerance to excessive boron (Richards 1954). In addition, there appears to be an overlap between beneficial and injurious effects of boron, and any conception of an optimum concentration of soil boron is theoretical and

TABLE 3.3

MICRONUTRIENT AND TRACE ELEMENT CONTENT OF SAGEBRUSH LEAVES[1]
COLLECTED FROM THE DIFFERENT SOIL SERIES ON RBOSP TRACT C-a

Soil Series	Boron	Copper	Manganese	Iron	Zinc	Molybdenum	Arsenic	Cadmium	Chromium	Cobalt
Glendive	36	7.0	56	330	16	0.7	0.20	0.10	1.9	0.05
Rivra	40	7.1	58	360	17	0.8	0.15	0.10	1.6	0.20
Havre	38	10.0	53	130	14	1.0	0.45	0.04	0.8	0.05
Piceance	42	12.0	61	300	20	0.7	0.20	0.10	1.5	<0.05
Yamac	39	9.9	73	230	24	0.9	0.15	0.12	1.0	0.20
Redcreek	30	7.6	58	170	22	0.6	0.15	0.11	0.8	0.10
Rentsac	47	8.4	50	240	17	0.9	0.15	0.06	1.2	0.30
Castner	48	7.0	41	200	12	0.5	0.20	0.06	1.4	0.15

	Mercury[2]	Antimony	Vanadium	Uranium	Nickel	Lead	Selenium
Glendive	.070	<0.5	<1	0.04	1.3	2.0	0.05
Rivra	.065	<0.5	<1	0.04	1.0	2.0	0.10
Havre	.065	0.5	<1	0.04	2.2	1.5	0.30
Piceance	.075	<0.5	<1	0.03	0.9	2.5	0.10
Yamac	.065	<0.5	<1	0.03	0.9	2.5	0.20
Redcreek	.075	<0.5	<1	0.02	0.8	1.5	0.15
Rentsac	.075	<0.5	<1	0.05	0.9	2.5	0.10
Castner	.085	0.9	<1	0.04	0.7	2.5	0.05

[1]Concentrations expressed in ppm in dry matter

[2]Concentrations expressed in ppb in dry matter

relative to numerous factors (Eaton 1944). Boron content of surface soils of tract ranged from less than 0.5 ppm to 1.9 ppm and averaged 0.7 ppm. Boron concentrations in this range should neither be toxic nor restrictive to plant growth. Boron concentrations of subsurface soils did not significantly differ from surface concentrations.

2. Copper

Kubota (1975) found that the total copper concentration in soils derived from shales averaged 18.7 ppm. Other authors (Swaine 1955, 1960; Mitchell 1964; Presant 1971) cite values from 14 to 20 ppm as the average concentration of total copper. From 10 to 50 percent of the total copper in soils is in a plant-available form (Mitchell 1964), thus plant-available copper should average from approximately 2 to 9 ppm. Extractable copper ranged from 0.5 to 13.6 ppm and averaged 2.1 ppm in surface soils and 0.8 to 4.7 ppm averaging 2.8 in subsurface soils. These parameters suggested that the copper concentration on tract was normal for soil and not restrictive to plant growth.

3. Manganese

Manganese is an essential component of plant and animal tissues and is among the least toxic of trace elements to animals (Underwood 1971). However, manganese phytoxicities are not uncommon in very acid soils or water-logged soils (Kubota and Allaway 1972), but cases of manganese toxicity in undisturbed semi-arid regions of the west have not been observed. In prairie soils, extractable manganese averages 48.7 ppm (Wali and Freeman 1973). The manganese concentration of the tract averaged 30 ppm for surface soils and 28 ppm for subsurface soils. The manganese concentration in the study did not suggest the possibility of deficiency or toxicity problems.

4. Iron

While iron is least available in alkaline soils, iron deficiencies in non-agricultural areas of the west are probably uncommon. Cases of iron toxicities under natural conditions have not been documented (Wallihan 1966), even when the total iron concentration exceeds 5 percent (Murphy and Walsh 1972). Total iron for the Piceance Creek basin, Colorado, ranges from 1.5 to 2.0 percent (Ringrose et al. 1976). Surface soils of tract averaged 81 ppm extractable iron and subsurface soils averaged 122 ppm. Ryan et al. (1975) reported that DTPA extractable iron in rangeland soils is not considered deficient until concentrations drop below approximately 2 ppm.

5. Zinc

Extractable zinc in soils commonly ranges from less than 1 ppm to 40 ppm, although some plants have been grown on soils containing more than 700 ppm extractable zinc with no apparent toxicity (Singh and Steenberg 1975; Mitchell 1964). An extractable zinc level of less than 0.8 ppm is considered deficient for crops such as corn, but zinc deficiencies have not been reported in noncultivated areas. The DTPA extractable zinc averaged 1.4 ppm for surface soils and 1.2 ppm for subsurface soils on the tract. While many soil intervals sampled had less than 0.8 ppm zinc, at least one interval at any given sampling had more than 0.8 ppm zinc. In no case was the entire plant rooting zone deficient in zinc. Zinc deficiency symtoms were not noted in the vegetation growing on tract.

6. Molybdenum

While molybdenum is essential for normal plant development, plants occasionally accumulate large amounts of this element (Johnson 1966). Plants growing on wet alkaline floodplains and on alkaline alluvial fans are more prone to accumulate toxic amounts of molybdenum than plants growing on upland sites (Kubota 1975). The total molybdenum content of

soil averages 2 ppm and the most commonly cited upper range for total molybdenum is 5 ppm (Hawkes and Webb 1962, Swaine and Mitchell 1960; National Academy of Sciences 1974). Information on the expected soil concentration of anion exchangeable molybdenum is lacking, but extensive analysis of overburden samples have shown that the concentrations of molybdenum on tract were quite low, averaging 0.3 ppm for both surface and subsurface soils.

7. Chloride

Chloride is the most recent element to be confirmed as essential to plant growth. However, chloride deficiencies have not been positively identified and suspected deficiencies are rare. The lack of deficiencies is related to the fact that plants require very little chloride for normal growth and that chloride is widely distributed in nature. Cases of chloride toxicity have been documented and usually occur in poorly drained areas that receive runoff from other areas or in coastal regions (Eaton 1966).

Chloride found in surface and subsurface soils of the tract appeared to be of the magnitude expected for semi-arid alkaline regions.

G. Organic Matter

Organic matter influences chemical and physical traits of soil far out of proportion to the small quantities generally present. Organic matter commonly accounts for at least half of the cation exchange capacity of soils and is very important to the stability of soil aggregates. In addition, organic matter supplies energy and other constituents necessary for microbial activity. Soil organic matter generally ranges from less than 1 percent to 10 percent and averages approximately 3 percent in arid regions (Brady 1974). Both precipitation and temperature have been recognized as important factors in determining the organic matter content of soils (Jenny 1941).

Surface soil organic matter on tract averaged 2.1 percent, a value typical for arid regions. The range in percentage organic matter was from 0.1 to 16.8. Soil horizons containing more than 10 percent organic matter were confined to the surface and occurred in areas where there was an unusually deep accumulation of litter. Intervals of surface soils with less than 1 percent organic matter were generally below 50 cm. The amount of organic matter in subsurface soils was generally low and ranged from 0.4 to 5.3 percent averaging 1.9 percent.

H. Gypsum Requirement

The gypsum requirement is an attempt to determine the amount of calcium required to replace sodium on the soil exchange complex when data on cation exchange capacity and exchangeable sodium are not available. Determining this requirement involves the use of an arbitrary procedure and does not measure a distinct chemical property of the soil. The gypsum requirement is positively correlated with exchangeable sodium by means of a regression equation (Richards 1954). Use of gypsum to reclaim sodic soils has been previously discussed. Briefly, gypsum supplies water soluble calcium to the soil. This calcium then replaces sodium held on the soil exchange complex. The gypsum requirement for surface and subsurface soils of Tract C-a was low, not atypical for semi-arid regions having alkaline soils.

I. Lime Requirement

The lime requirement is an indication of how much $CaCO_3$ or its equivalent must be applied to soil to increase the pH to 7.0 (Peech 1965). The lowest pH on tract was 6.9, and this very slight degree of acidity does not affect plant growth. Generally, soil pH must be well below 6.0 before the use of lime is considered. As expected, the lime requirement for all soils off tract was zero.

J. Trace Elements

Those elements which are not essential for normal plant growth, but which may be absorbed and accumulated by plants, are discussed in this section. The concentration of certain trace elements in surface and subsurface soils is of interest because plants may absorb enough of a particular trace element to be a potential threat to domestic or wild herbivores. Through various indirect means, trace elements in soils can be transferred to humans. It is also possible that high soil concentrations of some trace elements will be phytotoxic.

The content of trace elements (except fluoride) (Table 3.3) was measured in sagebrush leaves collected from plants occurring on the various soil series on Tract C-a. Tissue analysis data will provide baseline information regarding acceptable levels of trace elements in sagebrush leaves on Tract C-a. These present levels are assumed to be non-toxic to the plan

Most of the trace element content of soil is bound in crystal lattice of the constituent rock-forming minerals. The proportion of such materials which undergo chemical and physical weathering is relatively minor and the amounts of trace elements available for pedological translocations are small. Thus, few changes in trace element concentration as depth from the surface increases can be ascribed to pedological factors. If vertical differentiation does develop, it is generally related to trace element changes in the parent material (Swaine and Mitchell 1960). Few of the trace elements studied on Tract C-a and adjacent areas display consistent vertical patterns.

1. Arsenic

The mean concentration of total arsenic in soils varies between 5 and 10 ppm (Lisk 1972). Allaway (1975) gives 40 ppm as the maximum content of arsenic normally found in soil, while Mitchell (1964) found an upper value of 70 ppm. Although Liebig (1966) states that arsenic is more concentrated in the soils of arid regions than in soils of mesic

regions, Ringrose et al. (1976) report a mean total arsenic concentration in the Piceance Creek basin of 6.4 ppm. Liebig further states that dangers from arsenic poisoning are greatest where dust high in arsenic adheres to plant surfaces rather than the consumption of plants containing arsenic.

Total arsenic ranged from 3 to 40 ppm and averaged 10 ppm in surface soils and 8 ppm in subsurface soils. In view of the literature cited above, these soils are not unusual in their content of arsenic.

2. Cadmium

Cadmium, a toxicant to man and other organisms in virtually all of its chemical forms, is found mainly in various zinc ores. Cadmium and zinc appear to compete for certain organic ligands and zinc has an ameliorative effect on cadmium toxicity. The cadmium concentration of surface soils is generally less than 1 ppm. Soils with more than 1 ppm cadmium have usually been contaminated by agricultural or industrial chemicals (National Academy of Sciences 1974; Page and Bingham 1973). Some soil properties appear to influence plant absorption of cadmium. Williams and David (1973) note that plant uptake of cadmium is substantially lower in soils with a high cation exchange capacity than in soils with a low cation exchange capacity. Lagerwerff (1971) and Lisk (1972) found that while many plants easily absorbed cadmium from the soil, absorption decreases as pH increases.

Surface and subsurface soils of tract consistently contained less than 0.5 ppm of total cadmium. A concentration of this magnitude is expected for undisturbed areas. The average concentration of total cadmium in the study area was substantially below the detection limit of 0.5 ppm. A study of the soils of the Piceance Creek basin and other areas in northwestern Colorado revealed that total cadmium averages 0.13 ppm and ranges from 0.017 to 0.570 ppm (Mahmoud 1977).

3. Chromium

Chromium is widely distributed in nature and while there is no conclusive evidence showing that it is essential for plant growth, chromium is required by animals. However, the overall nutritional significance and biochemical role of chromium is unknown. Cases of chromium toxicity are rare and a wide margin of safety exists between amounts generally ingested and those likely to induce injury (Norrish 1975; Pratt 1966a; Underwood 1971). Chromium as a plant toxicant has been recognized since the turn of the century, but naturally occurring toxicities appear to be limited to serpentine soils where the chromium content ranges from 2000 to 3500 ppm (Pratt 1966a; Swaine and Mitchell 1960). After measuring the chromium in selected soils of the United States, Shacklette et al. (1971b) concluded that total chromium averages 53 ppm and ranges from 1 to 1500 ppm. For Tract C-a, total chromium ranged from 20 to 65 ppm and averaged 44 ppm for surface soils and 40 ppm for subsurface soils. These values were very close to the chromium content typical of soils, and were in close agreement to the 60 ppm mean concentration for the Piceance Creek basin (Ringrose et al. 1976).

4. Cobalt

Animals, especially ruminants, require an adequate supply of cobalt in their diet, and soils should contain approximately 7 ppm cobalt to support healthy livestock. Some soil microorganisms, notably those that are responsible for nitrogen fixation, also require cobalt (Mitchell 1964; Swaine and Mitchell 1960). Alkaline soils quickly convert soluble cobalt to forms that are not available to plants and cobalt fertilization may be effective in preventing cobalt deficiencies in ruminants. Excessive levels of cobalt are not very toxic to either plants or animals (Allaway 1975).

An average of 7 ppm in surface soils and 6 ppm in subsurface soils, and a range of 1 to 35 ppm total cobalt, occurred on tract. This average

and range is almost identical to that cited by Hawkes and Webb (1962) and Ringrose et al. (1976). Vegetation in some portions of the study area may not have contained sufficient cobalt to support rapid animal development. However, such areas were localized and therefore insignificant when the overall grazing pattern is considered.

5. Fluoride

The earth's crust contains about 800 ppm fluoride and soils contain from 10 to 7070 ppm fluoride. Neutral and alkaline soils inactivate fluoride, probably in a reaction with calcium and other soil constituents that convert soluble fluoride to insoluble forms. Thus, fluoride content of plants is not appreciably affected by the amount of total fluoride in the soil. While excessive fluoride can be very toxic to plants and animals, cases of toxicity are limited to very acid soils and industrialized areas with high atmospheric levels of fluoride (National Academy of Sciences 1974; Allaway 1975).

Soils of the tract contained from 30 to 1150 ppm total fluoride and averaged 597 ppm in surface soils and 374 in subsurface soils. These levels appeared normal and nontoxic for alkaline soils. Ringrose et al. (1976) reported mean fluoride concentrations of 490 ppm for the Piceance Creek basin with a range from less than 400 to 1600 ppm.

6. Mercury

Mercury occurs widely in low concentrations in the biosphere and has long been known as a toxicant. This element is considered nonessential for living organisms. Mercury content of soils is generally low, and average concentration of total mercury in soils is approximately 100 ppb (Potter et al. 1975; Shacklette et al. 1971a). The average concentration of mercury on the tract was 24 and 28 ppb for surface and subsurface soils, a level substantially below the average soil concentration. The highest level of mercury detected in the study area was 110 ppb. These values are in close agreement with those reported by Ringrose et al.

(1976) for the Piceance Creek basin. As much as 4600 ppb of mercury has been found in supposedly uncontaminated surface soils (Shacklette et al. 1971a).

7. Antimony

In studies of soils in the Powder River basin of Wyoming and Montana, antimony in surface and subsurface soils ranged from 0.60 to 2.1 ppm (Anderson et al. 1975). Total antimony has a rather uniform value of 2.1 ppm and ranges from 1.6 to 2.4 ppm in other soils (Presant 1971). Ringrose et al. (1976) report mean antimony concentration of 0.9 ppm and a range of less than 0.14 to 4.5 ppm for areas proximal to tract. On tract, antimony averaged about 1 ppm and ranged from less than 1 ppm to 3 ppm. These low values appeared to be normal for surface and subsurface soils.

8. Vanadium

Vanadium is a component of all soils and small amounts of this element are normally absorbed by plants. Clear proof that this element is required by higher plants or by higher animals has yet to be produced. However, some species of algae and bacteria require vanadium and there is increasing evidence that many animals require small amounts of vanadium. Under field conditions, there have been no reports of vanadium deficiencies or toxicities (Underwood 1971; Pratt 1966b). Normal concentration of vanadium in soil is approximately 100 ppm and the range is from about 20 to 500 ppm (Mitchell 1964; Lisk 1972; and Ringrose et al. 1976). Vanadium averaged about 58 ppm and ranged from 30 to 143 ppm for surface and subsurface soils of the tract, indicating a normal concentration of vanadium in these soils.

9. Selenium

Traces of selenium can be detected in most soils and excessive amounts can occur in arid regions where the soil is derived from seleniferous

rock and precipitation is insufficient to leach selenium below the plant rooting zone. When this element is present in excessive amounts in soil, it can inhibit the growth of some plant species. But a more serious problem arises when plants absorb excessive selenium from soil and are then ingested by livestock. However, selenium is an essential element for proper animal development (Beath 1959; Patel and Mehta 1970; Underwood 1971). Normal soils contain from 100 to 2000 ppb total selenium and from less than 10 to approximately 500 ppb water soluble selenium (Swaine and Mitchell 1960; Patel and Mehta 1970). Total selenium concentrations in soils of the Piceance Creek basin range from about 110 to 1200 ppb and average 280 ppb (Ringrose et al. 1976). The range of available selenium has yet to be established for soils, but would have an upper range between 500 and 2000 ppb.

Available selenium in surface and subsurface soils of Tract C-a averaged about 35 ppb and ranged from 10 to 500 ppb. This concentration of selenium on the tract did not suggest the possibility of toxicity problems.

10. Nickel

Evidence that nickel, a relatively nontoxic element, is essential for plants and animals has not yet appeared. Cases of nickel toxicities are rare, but may occur naturally on serpentine soils which are typically high in nickel. Swaine and Mitchell (1960) found that ammonium acetate extractable nickel ranges from 3.5 to 11.8 ppm for well-drained podzol soils. Several investigators have found that approximately 10 ppm of ammonium acetate extractable nickel is phytotoxic (Vanselow 1966).

Surface and subsurface soils within Tract C-a contained an average of about 0.8 ppm of ammonium acetate extractable nickel ranging from 0.3 to 2.4 ppm. These levels were normal for soils and nontoxic to plants.

11. Lead

Lead is a natural component of uncontaminated soils and of little consequence to the biota. Plant uptake and translocation of lead is

minimal under normal conditions. Factors that influence lead movement include soil traits and the presence of ligands that complex with lead and prevent its movement across cell walls and throughout the plant. Thus, plants effectively exclude most lead from above-ground parts and the small amount of lead that is translocated to shoots and leaves is of little consequence to grazing animals. Lead ingested by livestock, under usual conditions, is largely sequestered in bone and is not transferred to the human food cycle (Rains 1975; National Academy of Sciences 1974; Wilson and Cline 1966). Working in Scotland, Swaine (1955) found that surface soil concentrations of ammonium acetate extractable lead averaged 0.45 ppm and range from 0.05 to 3.60 ppm of ammonium acetate extractable lead.

Surface soils of Tract C-a contained from 0.7 to 4.0 ppm ammonium acetate extractable lead and averaged 1.6 ppm. While these levels were slightly higher than those found by Swaine, there was no indication that the level of soil lead was of any unusual biological significance in the study area. Subsurface soils contained considerably lower concentrations of lead ranging from 0.1 to 0.6 ppm and averaging 0.4 ppm.

K. Background Radioactivity

Background radioactivity was measured in terms of the concentration of uranium (or chemical uranium), equivalent uranium, equivalent thorium, radioactive potassium, and radium.

Chemical uranium averages 2.7 ppm for the earth's crust, 3.2 ppm in shale, and 4.8 ppm in granite (Krauskopt 1967). Equivalent uranium is of the same general magnitude as chemical uranium, while equivalent thorium is approximately three times the concentration of chemical uranium. If a system is in equilibrium, 1 ppm of chemical uranium contains 0.43 pico curies per gram of radium 226. High amounts of radium can be a radiological hazard. However, chemical uranium becomes a chemical toxicant long before it becomes a radiation hazard. Total potassium in the earth's crust averages approximately 2.5 percent and, by convention, this

figure is reported as potassium radioactivity in background radioactivity data. However, only 0.0118 percent of the total potassium is radioactive and in most soils this potassium contributes most of the radioactivity (Bowen 1966).

The background radioactivity of Tract C-a was low and within the ranges expected. None of the soil types showed any unusual concentrations of the various components of background radioactivity and posed no danger to living organisms. These soils are slightly out of radiological equilibrium, but this is the general case with soils. Because the chemical uranium was slightly less than equivalent uranium, the radium was slightly greater than would be expected on the basis of chemical uranium alone. This slight deviation from equilibrium was common for soils where chemical uranium is subject to removal via weathering.

Only one component of background radioactivity, potassium radioactivity, showed a statistically significant change with depth. Potassium radioactivity was higher in the surface sampling interval than in the three subsurface intervals. A similar distribution pattern also occurred for available and water soluble potassium. Plant absorption and accumulation of potassium may influence the distribution of radioactive potassium.

L. Water-Holding Capacity

Water-holding capacity is a measurement of the amount of water retained by a soil at a given level of suction. When measured at 1/3 bar (4.85 psi) suction pressure, the water-holding capacity approximates the amount of water retained by a soil after free drainage has ceased. The capacity at 15 bars (220 psi) suction pressure approximates the upper limit at which most plants are unable to absorb water from the soil. The amount of water retained between these two extremes is termed the plant-available moisture capacity, and serves as an index to the amount of water available for plant absorption. Nishimura (1974) suggested that soil used in reclamation has a minimum plant-available moisture capacity of approximately 7 percent to insure that the soil has the potential

to retain sufficient water for normal plant growth. Soil texture, structure, and organic matter are the main factors in determining water-holding capacity. Soils of tract had sufficient water-holding capacity to adequately support active plant growth.

M. Texture

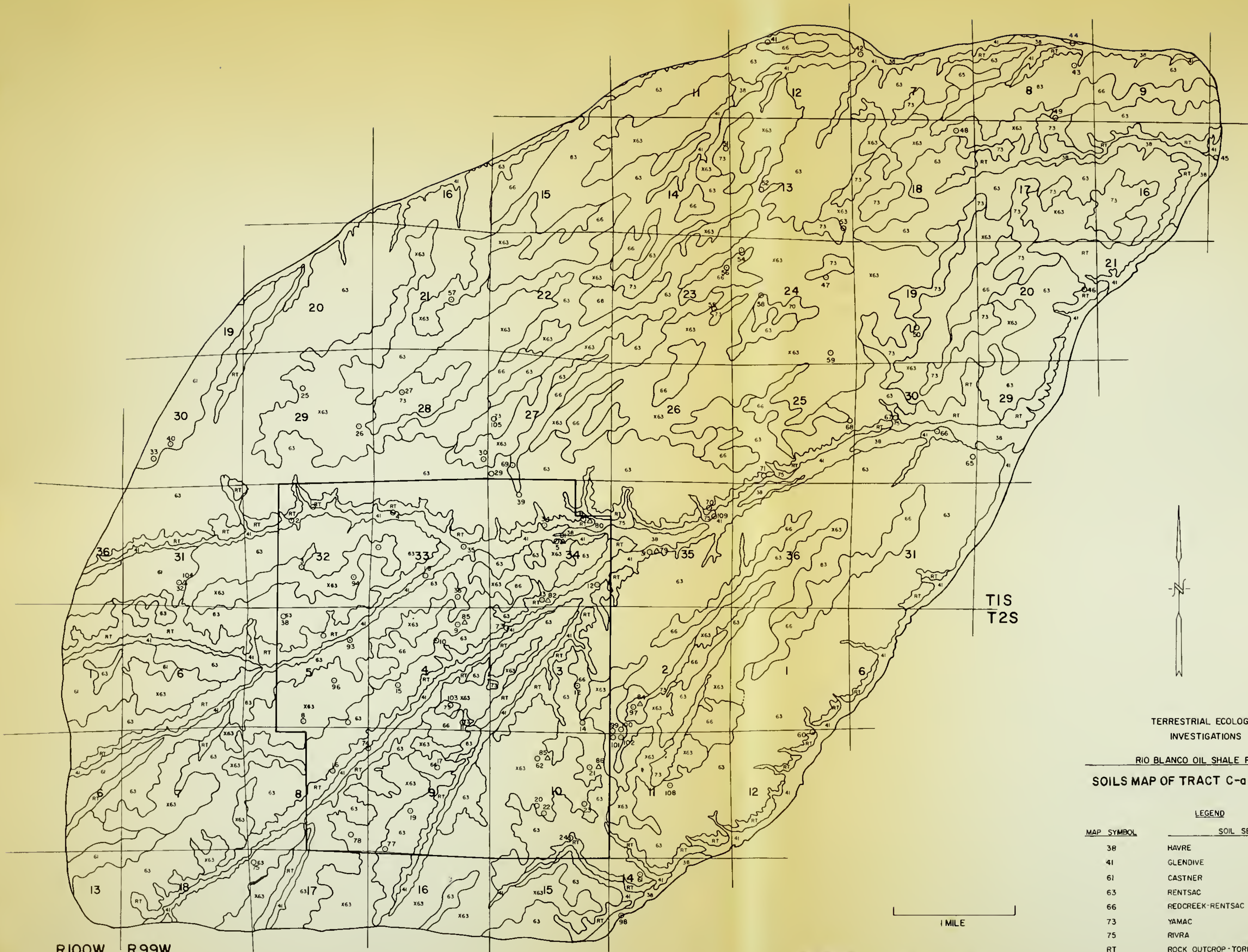
Texture is an important physical trait of soils in that it influences the nutrient-supplying ability of soil as well as the supply of air and water to plants' roots. Optimum soil texture varies with climatic conditions. In semi-arid regions, the production of native vegetation is greater on sandy soils than on medium to fine textured soils. In sandy soils, the infiltration rate is rapid so there is little water loss through surface runoff. Additionally, less moisture is held per unit depth in sandy soils so less moisture is lost to surface evaporation. However, sufficient fine-textured material must be present to retain adequate amounts of water (Berg and Barrau 1973).

Soils of tract were generally in the loam category and ranged from a loamy sand to a clay loam. Most subsurface soils were in the coarse to medium texture categories. These soils contained sufficient fines to retain adequate amounts of water.

Soil material suitable for top dressing in reclaimed areas varied in depth from less than 0.5 m to over 1.5 m. Rock is the primary factor limiting use of certain soils for reclamation.

N. Soil Series

Nine soil types consisting of six unique soil series and three soil complexes were identified within the study area (Figure 3.1). The areal distribution of each soil type was mapped. A preliminary soils map and description of soil types of Tract C-a (available from AOSS) was prepared by the Soil Conservation Service (SCS). This map was expanded to include the entire study area and refined through field reconnaissance and soil sampling into a final soils map (Figure 3.1).



TERRESTRIAL ECOLOGICAL INVESTIGATIONS

RIO BLANCO OIL SHALE PROJECT

SOILS MAP OF TRACT C-a AND VICINITY

LEGEND

MAP SYMBOL	SOIL SERIES
38	HAVRE
41	GLENDIVE
61	CASTNER
63	RENTSAC
66	REDCREEK-RENTSAC COMPLEX
73	YAMAC
75	RIVRA
RT	ROCK OUTCROP-TORRIORTHENT COMPLEX
X63	RENTSAC-PICEANCE COMPLEX

PREPARED BY
COLORADO SCHOOL OF MINES RESEARCH INSTITUTE

Figure 3.1

A representative pedon was selected for each soil series mapped. These pedons were described using standard SCS methods and terminology. A sample was taken of each soil horizon and analyzed in the laboratory. (Detailed methods and results are presented in RBOSP's 9th Quarterly Report.) A detailed summary of the results of the study of each soils series follows (a more detailed discussion of the soil series of Tract C-a and vicinity may be found in RBOSP Progress Report 9 (1976).

The 0-10 and the 10-50 cm sampling depths were used to compare soils traits of six of the more common soil series (Table 3.4). These two sampling intervals were used because differences in soil series traits are most evident in surface and near-surface soils where pedogenetic (soil forming) processes are taking place.

Over 70 percent of surface soils (upper 1.5 m) of tract was dominated by two soil types (Table 3.5), the Rentsac series (46 percent), and the Rentsac-Piceance complex (27 percent). Pinyon pine, Utah juniper, and sagebrush were dominant vegetation types of these soils. The major portion of the remaining area consisted of the Rock Outcrop-Torriorthent complex (11 percent), the Glendive series (9 percent) and the Redcreek-Rentsac complex (6 percent). Principle vegetation types of these soils included sagebrush, rabbitbrush, greasewood, pinyon pine, Utah juniper, and shadscale.

TABLE 3.5

SOIL TYPES, % OF AREA, AND DOMINANT VEGETATION ON EACH SOIL TYPE OF TRACT C-a

Soil Type	% of Tract	Dominant Vegetation Types
Rentsac Series	46	Pinyon-juniper, sagebrush
Rentsac-Piceance complex	27	Pinyon-juniper, sagebrush
Rock Outcrop-Torriorthent complex	11	Shadscale, pinyon-juniper
Glendive series	9	Sagebrush, rabbitbrush, greasewood
Redcreek-Rentsac complex	6	Pinyon-juniper, sagebrush
Rivra, Yamac & Havre series	1	Sagebrush, rabbitbrush, greasewood

TABLE 3.4

CHEMICAL AND PHYSICAL TRAITS OF THE MAJOR SOIL SERIES(1)

Soil Series	pH in Water	pH in 0.01M $CaCl_2$	Soluble Salt Electrical Conductivity mmhos/cm (2)	Soluble Salt Electrical Conductivity mmhos/cm (3)	Sodium Water Soluble (milliequivalents/100 g)	Sodium NH_4 Acetate Soluble (milliequivalents/100 g)	Cation Exchange Capacity (milliequivalents/100 g)	Exchangeable Sodium Percentage
Glendive	8.5	7.9	0.82	3.4	0.76	2.33	29.4	5.2
Redcreek	8.2	7.6	0.55	2.4	0.45	1.51	39.3	2.7
Yamac	8.3	7.5	0.39	1.6	0.42	1.59	42.3	2.9
Rentsac	8.2	7.6	0.42	1.6	0.33	1.50	42.2	2.8
Torriorthent	8.3	8.1	2.21	8.8	3.17	5.46	25.3	9.1
Piceance	8.4	7.8	0.31	1.3	0.39	1.35	40.7	2.4

Soil Series	Ammonium ppm	Nitrate ppm	Phosphorus $NaHCO_3$ Extractable ppm	Potassium Available ppm	Water Soluble Magnesium ppm	Water Soluble Calcium ppm	Water Soluble Potassium ppm	Sulfate ppm	Boron ppm	DTPA Extractable Copper ppm	DTPA Extractable Manganese ppm	DTPA Extractable Iron ppm	DTPA Extractable Zinc ppm
Glendive	10.1	4.8	23.0	646.1	15.8	65.1	26.8	295.7	0.7	1.6	30.7	95.8	1.7
Redcreek	9.8	1.8	23.1	348.3	12.4	48.6	10.6	190.7	0.7	1.2	49.0	115.0	1.5
Yamac	9.2	1.8	12.3	489.4	7.7	33.6	7.6	184.2	0.5	1.4	34.9	97.8	1.1
Rentsac	9.5	2.3	11.3	264.0	6.3	41.4	5.5	133.5	0.6	1.7	37.2	104.0	1.4
Torriorthent	11.1	10.3	7.3	151.1	32.0	225.4	8.8	1246.0	0.7	3.1	20.8	76.3	1.2
Piceance	10.2	1.5	8.7	412.7	7.4	41.5	7.8	245.9	0.6	1.8	44.3	83.3	1.4

Soil Series	Molybdenum Anion Exchangeable ppm	Organic Matter %	Gypsum Requirement MEQ/100 g	Lime Requirement lb $CaCO_3$/acre	Total Phosphorus ppm	Total Arsenic ppm	Total Cadmium ppm	Total Chloride ppm	Total Chromium ppm	Total Cobalt ppm	Total Fluoride ppm	Total Mercury ppb
Glendive	0.4	3.4	0.3	0	533.1	7.7	0.5	935.7	47.3	7.5	585.7	18.8
Redcreek	0.3	3.5	0.3	0	526.0	5.7	0.5	836.7	45.0	8.1	436.8	16.0
Yamac	0.2	2.3	0.3	0	711.2	6.3	0.5	700.0	48.4	9.4	368.8	12.5
Rentsac	0.3	4.1	0.3	0	503.6	9.1	0.5	874.6	42.9	7.7	478.8	23.7
Torriorthent	0.4	2.0	0.4	0	455.1	14.3	0.5	1128.6	36.4	7.2	644.3	33.9
Piceance	0.3	2.7	0.2	0	572.9	8.1	0.5	769.2	43.1	8.2	433.1	15.1

Soil Series	Total Antimony ppm	Total Vanadium ppm	Selenium Available ppb	NH_4 Acetate Extractable Nickel ppm	NH_4 Acetate Extractable Lead ppm	Background Radioactivity Uranium ppm	Background Radioactivity Equivalent Uranium ppm	Background Radioactivity Equivalent Thorium ppm	Background Radioactivity Potassium Radioactivity %	Radium-226 Picocuries/g
Glendive	1.0	58.9	29.3	0.8	1.5	2.1	2.6	9.5	2.4	0.9
Redcreek	1.0	52.8	12.0	0.9	1.5	2.3	2.2	12.6	2.7	0.8
Yamac	1.0	61.6	11.3	0.8	1.1	2.1	2.3	11.5	2.7	0.8
Rentsac	1.1	56.8	18.0	0.8	1.5	2.2	2.9	9.6	2.4	1.1
Torriorthent	1.0	53.9	70.7	1.4	2.2	2.2	2.6	8.0	2.4	0.8
Piceance	1.0	62.7	13.9	0.9	1.3	2.1	3.1	11.3	2.5	1.0

Soil Series	Bulk Density g/cm3 (4)	Water-Holding Capacity, % (Dry Sample Wt. Basis) 1/3 Bar Suction	Water-Holding Capacity, % (Dry Sample Wt. Basis) 15 Bar Suction	Particle-Size Analysis, Wt. % Sand -2.0+ 0.05 mm	Particle-Size Analysis, Wt. % Silt -0.05 + 0.002 mm	Particle-Size Analysis, Wt. % Clay -0.002 mm	Textural Class
Glendive	1.03	23.9	11.8	42.0	47.2	10.8	Loam
Redcreek	1.28	22.1	12.1	47.6	40.4	12.0	Loam
Yamac	1.27	23.9	11.1	38.8	45.5	15.8	Loam
Rentsac	1.25	28.0	14.1	37.1	48.7	14.2	Loam
Torriorthent	0.93	25.1	11.1	30.8	58.5	10.8	Silt loam
Piceance	1.25	25.2	12.6	31.9	51.6	16.5	Silt loam

(1) Individual parameters express the mean value of the 0 to 10 plus the 10 to 50 cm depths.
(2) Sample to extract ratio: 1 to 2.
(3) Conductivity for a saturation extract based on 1 to 2 ratio conductivity data and the 1/3 bar water-holding capacity.
(4) Weighted average of bulk density of upper 50 cm of soil profile.

Values of pH for the six soil series were similar and had a range difference of only 0.3 units. The Torriorthent was the only series that was saline in the surface 50 cm and none of the series were sodic. The cation exchange capacity was lowest for the Glendive and Torriorthent series, the two series with the least amount of clay. The remaining series had similar cation exchange capacities. All series contained similar amounts of ammonium. Nitrate was unusually high in the Torriorthent series while extractable phosphorus was relatively high for the Glendive and Redcreek series. Water-soluble calcium, sodium, and sulfate were unusually high in the Torriorthent series, and available potassium was unusually low. Micronutrients did not show much variation from series to series, except for a slight increase in copper concentration in the Torriorthent series. Of the six series examined, the Glendive series appeared to have the best balance of nutrients and was rated as the most fertile. Similar concentrations of trace elements were found in all soil series with the exception of the Torriorthent. This series contained generally higher concentrations of trace elements, although none of the trace elements were outside the range considered normal and nontoxic for soils. Values of background radiation were very similar for all series. Physical traits showed little variation in both water-holding capacity and texture.

The most common soil types of the study area (Tract C-a and adjacent areas) were the Rentsac-Piceance complex, and the Redcreek-Rentsac complex Collectively, these soils dominated over 80 percent of the study area with the Glendive, Yamac, Castner, Havre and Rivra series, and the Rock Outcrop-Torriorthent complex found in remaining area.

Although most soils on tract, with the exception of soils of the Rock Outcrop-Torriorthent complex, appeared to have some surface soil suitable for top dressing material (topsoil), the Glendive series appeared to have the best balance of nutrients and the greatest depth of suitable soil material.

II. SOILS OF THE STUDY AREA

A thorough study of soils in areas proximal to Tract C-a not only aids in presenting a true picture of existing environmetal conditions for the region, but also provides valuable information upon which an environmental monitoring program can be based. Sampling intensity both on and off tract was fairly evenly divided, with slightly more than half of the surface soil sampling sites off tract. Chemical and physical properties of surface soils of the entire study area of Tract C-a and vicinity are presented in Table 3.6. Following is a discussion of how soil properties outside the boundaries of tract differ from the soil properties previously discussed for Tract C-a.

Soil traits of pH and ESP are essentially the same for Tract C-a as for the study area. Although soluble salt electrical conductivity was slightly higher for the study area than for tract, the difference was small. The primary reason for the difference was that almost one-third of the highly saline soil samples were from the 84 Mesa portion of the study area. Soils of the study area had an electrical conductivity of 3.5 mmhos/cm while 84 Mesa had soils which averaged 5.7 mmhos/cm of electrical conductivity.

With few exceptions, the concentration of plant macronutrients was of the same magnitude in both areas. Nitrate and available potassium were exceptions. Nitrate averaged 10.5 ppm on Tract C-a, as compared to 6.3 for the study area. Of the soils of the study area containing more than 30 ppm nitrate, over 70 percent were on Tract C-a. This was largely responsible for the higher average nitrate concentration of tract soils over those of the study area. The concentration of available potassium in surface soils of the study area averaged 385 ppm, 123 ppm higher than tract. These differences in macronutrient concentration were not unusual considering the heterogeneous nature of the soils found in the study area.

Micronutrients showed no significant variation when the study area was compared to tract. This lack of variation was also evident in the

TABLE 3.6

CHEMICAL AND PHYSICAL TRAITS OF SOILS OF THE STUDY AREA(1)

Parameter	pH in Water	pH in 0.01M $CaCl_2$	Soluble Salt Electrical Conductivity mmhos/cm (2)	Soluble Salt Electrical Conductivity mmhos/cm (3)	Sodium Water Soluble (milliequivalents/100 g)	Sodium NH_4 Acetate Soluble (milliequivalents/100 g)	Cation Exchange Capacity (milliequivalents/100 g)	Exchangeable Sodium Percentage
Mean	8.4	7.8	0.89	3.5	1.02	2.87	37.0	5.0
Range	6.9-9.9	6.1-9.2	0.10-11.50	0.5-59.0	0.02-19.48	0.03-30.1	10.3-89.2	0.01-53.46
Standard Deviation	0.5	0.4	1.5	6.5	2.0	3.7	13.3	9.3

Parameter	Ammonium ppm	Nitrate ppm	Phosphorus $NaHCO_3$ Extractable ppm	Potassium Available ppm	Water Soluble: Magnesium ppm	Water Soluble: Calcium ppm	Water Soluble: Potassium ppm	Water Soluble: Sulfate ppm	Water Soluble: Boron ppm	DTPA Extractable: Copper ppm	DTPA Extractable: Manganese ppm	DTPA Extractable: Iron ppm	DTPA Extractable: Zinc ppm
Mean	9.3	6.3	12.7	385.1	16.2	59.8	12.2	323.2	0.6	1.8	33.7	104.4	1.5
Range	0.4-35.2	<0.1-420.0	1.0-155.0	80.0-2540.0	0.4-319.7	3.6-679.0	0.9-190.0	5.0-6200.0	0.5-1.9	0.5-13.6	6-214	12-448	0.4-9.0
Standard Deviation	5.4	29.1	14.9	338.2	36.5	101.2	18.1	664.2	0.2	[illegible]	21.5	64.0	0.9

Parameter	Molybdenum Anion Exchangeable ppm	Organic Matter %	Gypsum Requirement MEQ/100 g	Lime Requirement lb $CaCO_3$/acre	Total: Phosphorus ppm	Total: Arsenic ppm	Total: Cadmium ppm	Total: Chloride ppm	Total: Chromium ppm	Total: Cobalt ppm	Total: Fluoride ppm	Total: Mercury ppb
Mean	0.3	2.9	0.4	0	541.8	8.4	<0.5	910.0	44.4	8.0	510.0	18.8
Range	0.1-2.4	0.1-21.8	0.2-6.0	0	95-1549	5-40	<0.5-0.5	200-2500	20-80	1-35	160-1150	10-110
Standard Deviation	0.2	2.5	0.6	0	198.5	5.7	<0.01	330.8	9.8	2.6	194.0	12.0

Parameter	Total: Antimony ppm	Total: Vanadium ppm	Selenium Available ppb	NH_4 Acetate Extractable: Nickel ppm	NH_4 Acetate Extractable: Lead ppm	Background Radioactivity: Uranium ppm	Background Radioactivity: Equivalent Uranium ppm	Background Radioactivity: Equivalent Thorium ppm	Background Radioactivity: Potassium Radioactivity %	Background Radioactivity: $Radium^{226}$ Picocuries/g
Mean	1.0	59.1	56.4	0.9	1.4	2.2	2.7	10.5	2.5	0.9
Range	1-3	20-110	10-2600	0.3-2.4	0.6-4.0	2-5	1-8	2-30	0.5-4.9	0.5-2.5
Standard Deviation	0.2	13.8	253.3	0.3	0.5	0.6	1.1	3.6	0.7	0.4

Parameter	Water-Holding Capacity, % (Dry Sample Wt. Basis): 1/3 Bar Suction	Water-Holding Capacity, % (Dry Sample Wt. Basis): 15 Bar Suction	Particle-Size Analysis, Wt. %: Sand -2.0 +0.05 mm	Particle-Size Analysis, Wt. %: Silt -0.05 +0.002 mm	Particle-Size Analysis, Wt. %: Clay -0.002 mm	Textural Class
Mean	25.7	12.6	39.1	47.0	13.9	Loam
Range	11.5-50.9	5.4-26.3	3.0-85.5	12.5-77.0	2.0-34.0	
Standard Deviation	7.3	3.5	17.4	13.8	6.3	

(1) n= 312.
(2) Sample to extract ratio: 1 to 2.
(3) Conductivity for a saturation extract based on 1 to 2 ratio conductivity data and the 1/3 bar water-holding capacity.

comparisons of trace elements. However, available selenium was an exception and its concentration was substantially lower on Tract C-a (averaging 34 ppb) than in the study area (averaging 56 ppb). All sampling sites containing abnormally high amounts of selenium were located outside Tract C-a boundaries.

Background radioactivity and the physical traits of texture and water-holding capacity showed no significant change from the study area to Tract C-a. On the average, soils on Tract C-a contained slightly more silt and correspondingly less sand than in the study area. However, differences of this magnitude were not thought to be biologically significant.

III. SOIL TRAITS AS INFLUENCED BY VEGETATION

Vegetation plays an important role in the redistribution of soil constituents. Plants absorb soil constituents from a large area and concentrate them in a relatively small area, thus contributing to the vertical gradients in soil. Certain types of vegetation will impart different traits to the soil. Rooting pattern, life span, phenology, elemental composition, and other factors differ from one plant species to another and can significantly influence many soil traits. Comparison of prairie soils with forest soils is the classical example of the influence of different types of vegetation on soil traits (Jenny 1941).

Chemical and physical traits of near-surface soils (0-50 cm) of the study area were grouped on the basis of the dominant vegetation at the sampling site. Mean values of soil traits on the basis of dominant vegetation are presented in Table 3.7. Not all of the vegetative types found in the study area were included. A limited number of samples were taken on sites where aspen, Douglas fir, grasses, or riparian vegetation dominated. The number of soil samples collected on these sites was not sufficient to allow for meaningful comparisons.

TABLE 3.7

SOIL TRAITS AS RELATED TO DOMINANT VEGETATION

Dominant Species	pH in Water	pH in 0.01M $CaCl_2$	Soluble Salt Electrical Conductivity mmhos/cm (1)	Soluble Salt Electrical Conductivity mmhos/cm (2)	Sodium Water Soluble (milliequivalents/100 g)	Sodium NH_4 Acetate Soluble (milliequivalents/100 g)	Cation Exchange Capacity (milliequivalents/100 g)	Exchangeable Sodium Percentage
Sagebrush	8.3	7.7	0.34	1.7	0.36	1.36	39.3	2.5
Pinyon-Juniper	8.2	7.6	0.47	1.9	0.39	1.50	41.3	2.7
Shadscale	8.2	8.0	0.87	3.5	0.53	1.74	25.4	4.8
Mixed Brush	8.0	7.5	0.42	1.4	0.07	0.54	62.3	0.8
Rabbitbrush	8.3	7.9	0.74	2.4	0.43	0.86	34.0	1.3
Greasewood	9.0	8.3	2.96	12.3	5.02	9.36	26.6	16.3

Dominant Species	Ammonium ppm	Nitrate ppm	Phosphorus $NaHCO_3$ Extractable ppm	Potassium Available ppm	Water Soluble Magnesium ppm	Water Soluble Calcium ppm	Water Soluble Potassium ppm	Water Soluble Sulfate ppm	Water Soluble Boron ppm	DTPA Extractable Copper ppm	DTPA Extractable Manganese ppm	DTPA Extractable Iron ppm	DTPA Extractable Zinc ppm
Sagebrush	9.0	1.8	12.1	412.0	7.2	38.1	8.8	172.1	0.6	1.5	37.4	89.1	1.4
Pinyon-Juniper	10.4	2.0	17.1	311.9	9.2	44.5	8.4	154.4	0.7	1.5	42.1	111.8	1.5
Shadscale	11.8	3.6	6.3	152.5	30.6	225.0	7.1	818.4	0.6	2.9	21.5	77.2	1.2
Mixed Brush	13.8	3.5	11.2	660.0	5.9	47.8	13.5	133.4	0.6	2.2	51.3	161.5	2.0
Rabbitbrush	12.8	3.0	26.9	876.0	19.0	74.3	35.4	264.1	0.7	1.8	30.4	65.1	1.6
Greasewood	10.1	12.8	18.5	674.5	19.4	64.4	21.5	1073.3	0.8	2.2	36.6	147.2	1.8

Dominant Species	Molybdenum Anion Exchangeable ppm	Organic Matter %	Gypsum Requirement MEQ/100 g	Lime Requirement lb $CaCO_3$/acre	Total Phosphorus ppm	Total Arsenic ppm	Total Cadmium ppm	Total Chloride ppm	Total Chromium ppm	Total Cobalt ppm	Total Fluoride ppm	Total Mercury ppb
Sagebrush	0.3	2.8	0.3	0	558.4	8.1	0.5	838.4	46.0	8.1	463.2	16.5
Pinyon-Juniper	0.3	4.1	0.3	0	535.5	6.7	0.5	840.8	43.6	8.2	420.8	19.2
Shadscale	0.4	2.2	0.3	0	440.4	15.0	0.5	1058.3	34.6	6.8	646.7	32.5
Mixed Brush	0.4	6.8	0.9	0	607.1	11.3	0.5	691.7	45.1	8.7	506.7	18.8
Rabbitbrush	0.4	4.2	0.2	0	492.0	10.0	0.5	740.0	44.5	6.8	664.0	18.5
Greasewood	0.5	2.1	0.5	0	617.8	7.0	0.5	1100.0	47.5	8.4	551.0	21.5

Dominant Species	Total Antimony ppm	Total Vanadium ppm	Selenium Available ppb	NH_4 Acetate Extractable Nickel ppm	NH_4 Acetate Extractable Lead ppm	Background Radioactivity Uranium ppm	Background Radioactivity Equivalent Uranium ppm	Background Radioactivity Equivalent Thorium ppm	Background Radioactivity Potassium Radioactivity %	Background Radioactivity Radium^{226} Picocuries/g
Sagebrush	1.0	59.6	15.6	0.8	1.3	2.1	2.7	10.9	2.6	0.9
Pinyon-Juniper	1.1	55.4	14.8	0.9	1.5	2.2	2.5	11.1	2.5	0.9
Shadscale	1.0	62.9	16.7	1.3	2.3	2.3	2.4	8.3	2.1	0.8
Mixed Brush	1.0	68.3	14.2	1.0	1.1	2.1	2.9	10.9	2.8	0.9
Rabbitbrush	1.0	64.5	46.0	0.7	1.6	2.0	2.6	9.0	2.6	0.9
Greasewood	1.0	61.5	126.0	1.0	1.6	2.2	2.4	9.6	2.4	0.8

Dominant Species	Water-Holding Capacity, % (Dry Sample Wt. Basis) 1/3 Bar Suction	Water-Holding Capacity, % (Dry Sample Wt. Basis) 15 Bar Suction	Particle-Size Analysis, Wt. % Sand -2.0 +0.05 mm	Particle-Size Analysis, Wt. % Silt -0.05 +0.002 mm	Particle-Size Analysis, Wt. % Clay -0.002 mm	Textural Class
Sagebrush	24.4	12.3	37.9	47.3	14.8	Loam
Pinyon-Juniper	25.1	13.1	43.3	43.7	13.0	Loam
Shadscale	25.1	11.3	31.0	58.1	10.9	Silt loam
Mixed Brush	31.9	16.5	25.7	54.6	19.8	Silt loam
Rabbitbrush	30.9	14.6	27.6	56.7	15.7	Silt loam
Greasewood	24.1	10.5	38.8	51.2	10.1	Silt loam

(1) Sample to extract ratio: 1 to 2
(2) Conductivity for a saturation extract based on 1 to 2 ratio conductivity data and the 1/3 bar water-holding capacity.

The association of a particular type of vegetation with particular soils traits does not necessarily mean that the vegetation imparted these traits to the soil. Differences in parent material, relief, microclimate, and time influence soil traits and may mask the influence of vegetation or erroneously imply vegetative influence.

Big sagebrush, the most common plant species in the study area, was found on moderately alkaline, nonsaline, and nonsodic soils. Soluble salt electrical conductivity and ESP were low relative to the entire study area and relative to other species listed in Table 3.7. Concentrations of plant nutrients showed no significant variation from the study area. However, the concentration of water soluble nutrients was generally lower for sagebrush soils than for other vegetation types examined. Organic matter, trace elements, background radioactivity, and physical properties displayed no unusual values.

The nonsaline, nonsodic, and moderately alkaline soils of the pinyon-juniper vegetation type showed no unusual traits relative to surface and near-surface soils of the study area. These soils were very similar in chemical traits to those associated with sagebrush. Pinyon-juniper soils contained the least amount of silt and the greatest amount of sand for the vegetation types studied. Both pinyon and juniper apparently have a competitive advantage on sandy, and frequently rocky, soils.

Soils of the shadscale vegetation type were nonsaline and nonsodic, but the soluble salt electrical conductivity and the ESP were slightly higher than soils of other vegetative types. Fireman and Hayward (1952) found that soils under shadscale are higher in ESP and in electrical conductivity than soils outside the influence of this shrub. Similar results were reported by Sharma and Tongway (1973) for another species of *Atriplex*. These results imply that shadscale redistributes (directly or indirectly) sodium and other salts. Shadscale soils were unusually high in magnesium, calcium, and sulfate. Many of the trace elements, especially lead, nickel, mercury, and arsenic were slightly more concentrated in shadscale soils than in soils of other vegetative types.

Areas dominated by shadscale were generally located on steep canyon slopes where soils were poorly developed and very shallow. Parent material strongly influenced the chemical traits of the shadscale soils and probably accounts for most of the differences noted.

Mixed brush soils had the lowest pH, electrical conductivity, ESP, magnesium, and sulfate of those listed in Table 3.7. This suggests that leaching was more intense in this vegetative type than in the other types studied. Mixed brush was generally found on north-facing slopes in the higher areas of the study area. Such areas tended to be relatively moist and presumably more intensively leached. Extractable manganese, zinc, and iron were relatively high for these soils. Organic matter was also high and may be related to the deciduous nature of many shrubs of the mixed brush type. The annual shedding of leaves may increase the soil organic matter over that found in areas dominated by vegetation that retains leaves. In addition, leaves of deciduous plants generally decompose faster than leaves from nondeciduous plants. These soils had the least amount of sand and the greatest amount of clay. This may indicate a slightly more intense chemical and physical weathering of soil.

The degree of influence of rabbitbrush on soil traits appeared to be of the same low magnitude as indicated for sagebrush and pinyon-juniper. Extractable phosphorus and potassium were unusually high for these soils. Rabbitbrush generally dominated bottomland soils where sagebrush had been eliminated by burning. This burning may have increased the concentration of phosphorus and potassium (Uggla 1959). Other soil traits for rabbitbrush soils did not display unusual concentrations of elements relative to the study area or to other vegetation types studied.

Greasewood appeared to occur on a distinct soil type. Soils where greasewood dominated were saline, sodic, and strongly alkaline (See Table 3.7). Fireman and Hayward (1952) found that pH, electrical conductivity, and ESP are higher under greasewood plants than in open areas free from the influence of greasewood. They also found that greasewood leaves

contain a high proportion of its anions in the form of organic acids. When the leaves decompose and the various products are released to the soil, calcium and magnesium are displaced on the soil exchange complex and replaced with sodium, thus increasing both pH and ESP. Nitrate and sulfate are two micronutrients that were unusually high for the area dominated by greasewood. The possibility of greasewood influencing the distribution of these macronutrients is intriguing, but only speculative at this point. Micronutrient and trace element concentrations in areas dominated by greasewood were similar to concentrations in areas dominated by other forms of vegetation. However, selenium was the exception, and in greasewood dominated areas this element averaged 120 ppb as compared to 46 ppb for the 0-50 cm sampling depths of the entire study area. Greasewood is not listed as a plant that accumulates large amounts of selenium (Beath 1959). Ganje (1966) reported that areas which support an abundance of selenium-accumulating plants may have the surface soils enriched as plants decompose and release selenium to the surface soil. However, such selenium-accumulating plants were not observed in the greasewood area or in other parts of the study area. A reasonable explanation for the unusual concentration of selenium in greasewood dominated soils cannot be given at this time. Physical traits were in the range expected, except that greasewood soils had the least amount of clay for the vegetation types studied.

CONCLUSIONS

Chemical and physical properties of surface and subsurface soils of Tract C-a and vicinity were typical of semi-arid regions in the western United States. Although a limited number of areas had soils with saline or sodic materials in the surface soil profile, they appeared to offset plant growth only in an extremely limited area where these materials were of a high magnitude or occurred in the upper 50 cm of soil. Concentrations of macro- and micronutrients generally were within the ranges expected. However, some areas had unusually high concentrations of molybdenum. Trace element concentrations were within ranges considered normal for soils and nontoxic to plants and animals. Selenium was the only exception with about 3 percent of the sites sampl

(all occurring outside Tract C-a boundaries) containing more plant-available selenium than is normally found in soils of semi-arid regions. Since concentrations of trace elements in soils of Tract C-a were not of sufficient magnitude to be a potential threat to plants or animals, continued studies on trace elements in other components of the ecosystem are not recommended. Background radioactivity levels were low and within the range considered non-significant to living organisms. The soils were coarse to medium in texture and had the potential to retain sufficient water and nutrients for normal plant growth.

Soil suitable for surface reclamation of disturbed areas ranged in depth from 0 to 1.5 m. Rock was the most common factor limiting the depth of suitable reclamation soils, although in some areas the presence of sodic or saline material may also limit use.

Some soil traits increase while others decrease in value as a function of soil depth, but in general there are only a few significant correlations between soil depth and changes in chemical properties. Salinity, pH, and exchangeable sodium percentage significantly increased with depth. Trace element concentrations were generally constant throughout the surface and subsurface soil profiles.

Nine soil types consisting of six unique soil series and three soil complexes existed within the study area. The Torriorthent series was the only series that was saline near the surface. None of the series were sodic (alkali). Glendive and Torriorthent series had the lowest cation exchange capacity. Cation exchange capacity of the remaining series was similar. There was not much variation in micronutrients between soil series except for a slight increase in copper concentration in the Torriorthent series. Glendive soils had the best balance of nutrients and were the most fertile. Similar concentrations of trace elements were found in all soils except the Torriorthent soils. The Torriorthent soils generally had higher than average concentrations of trace elements although none were outside the range considered normal for soils and nontoxic. There was very little variation in texture and water-

holding capacity between the soil types. Most soils in the study area appeared to have some surface soil suitable for top dressing material except for the soils of the Rock Outcrop-Torriorthent complex.

Although there appeared to be a distribution overlap between certain plant communities and specific soil types, the vegetation did not appear to significantly affect soil traits. However, greasewood was found in saline, sodic, and strongly alkaline soils. Nitrate, sulfate, and selenium were also unusually high in greasewood dominated areas.

CHAPTER 2 - VEGETATION

ABSTRACT

Eight vegetation types (aspen, Douglas-fir, pinyon-juniper, mixed brush, sagebrush, bald, shadscale and riparian) were identified for the study area over a two-year period. Types were identified by the dominant overstory species, and the areal extent was defined by the interpretation of aerial color infrared (CIR) photography. The pinyon-juniper type was subdivided into three associations, based on topographic and physiognomic criteria. A vegetation map was developed to delineate the extent and location of these vegetation types and associations in the study area. The pinyon-juniper and sagebrush vegetation types were found to be the most extensive types in the study area. The distribution of vegetation types within the study area was found to be strongly influenced by topography and soil development.

Six tree species, 39 shrub species and 186 herbaceous species, of which 49 are classified as grass or grass-like, were identified for the study area. One formerly endangered plant species, a milkvetch (*Astragalus lutosus*), was located on the northern portion of the study area.

Human effects on study area vegetation communities are evident along major drainages where bottomland sagebrush was converted to pastureland during the early part of the twentieth century. These agricultural lands were for the most part abandoned and secondary succession, represented by dense rabbitbrush stands, is currently occurring on these disturbed sites. Livestock and feral horses have grazed the entire study area since the early twentieth century. These animals utilize the herbaceous stratum, and to some extent the shrub stratum, in nearly all vegetation types and

associations identified. Livestock have affected composition and abundance most directly in bottomland sites where summer water is available and grazing activity is intensified.

The objectives of the vegetation investigations were to identify the plant species present, define the structural and compositional organization of these species in recognizable associations, correlate floristics and phytosociology with biotic and abiotic environment and historic usage patterns, and map the predominant vegetation types.

VEGETATION TYPES

The phytosociological program included interpretation of aerial photographs and review of pertinent literature to determine the kind and extent of different vegetation types present in the study area. Quantitative ground measurements were employed during three seasons (Spring, Summer, Fall) over the two-year period, 1975-1976.

Vegetation type names were derived from the dominant overstory species present, which constitued a discrete mappable unit. Some vegetation types were subdivided into associations (variants of types) on the basis of certain compositional, edaphic, or seral criteria (Table 3.8).

A vegetation type map (see map pocket) delineates the areal extent and location of each vegetation type or association within the study area. This map was developed from interpretation of CIR aerial photography at scales of 1:600 and 1:24000, and from the results of quantitative group sampling within representative areas of each mapped type.

The study area was sampled with a series of stratified strip transects distributed over representative areas of each vegetation type. Tree, shrub, and herbaceous strata were sampled. The number of transects sampled in each type was proportional to the areal extent of that type within the study area boundaries.

TABLE 3.8

VEGETATION TYPES AND ASSOCIATIONS IDENTIFIED DURING 1974-1976 ON THE TRACT C-a STUDY AREA FOR RBOSP

- Aspen
- Douglas-Fir
- Mixed brush
- Pinyon-juniper
  - Pinyon-juniper - woodland
  - Pinyon-juniper - mixed brush
  - Pinyon-juniper - sagebrush
- Sagebrush
  - Upland sagebrush
  - Bottomland sagebrush
  - Greasewood
  - Rabbitbrush
- Bald
- Shadscale
- Riparian

Detailed descriptions of sampling methodolgy, data analysis and data presentation, and tabulation of sampling results are contained in the RBOSP Terrestrial Annual Report (1976). Results presented in this final report represent a summary of the data collected over the two-year study period, and are intended to support discussions of interactions between the plant cummunity and the abiotic environment and other biotic components in the Tract C-a study area.

Quantitative data for the tree and shrub strata were synthesized for all transects (except October 1974) over the two-year period to arrive at an average structural and compositional concept for each type (see Table 3.1 in RBOSP Progress Report 10 1977).

Quantitative data for the herbaceous stratum of each type and association were synthesized by season, so that seasonal trends in composition, diversity, and cover could be evaluated (Figure 3.2).

Eight vegetation types (aspen, Douglas-fir, pinyon-juniper, mixed brush, sagebrush, bald, shadscale, and riparian) were identified for the study area. Types were identified by the dominant overstory species and the areal extent of these areas defined by the interpretation of aerial color infrared (CIR) photography at scales of 1:6000 and 1:24000. The pinyon-juniper type was subdivided into three associations, based on topographic and physiognomic criteria. A vegetation map was developed at a scale of 1:24000 to delineate the extent and location of these vegetation types and associations in the study area. The pinyon-juniper and sagebrush vegetation types were found to be the most extensive types on the study area. General information (type, name, elevation, exposure, areal extent, soil, dominant species) regarding each vegetation type and association in the study area is presented in Table 3.9

The distribution of vegetation types within the study area was found to be strongly influenced by topography and soil development. The Douglas-fir and aspen types were restricted to cool north-facing exposures at the highest elevations. The mixed brush type dominated primarily by serviceberry shrubs, was widely distributed at higher elevations between 2100 and 2550 m (7000-8500 feet) and reached its maximum cover and density on north-facing slopes at higher elevations. The pinyon-juniper type, dominated by pinyon pine and Utah juniper

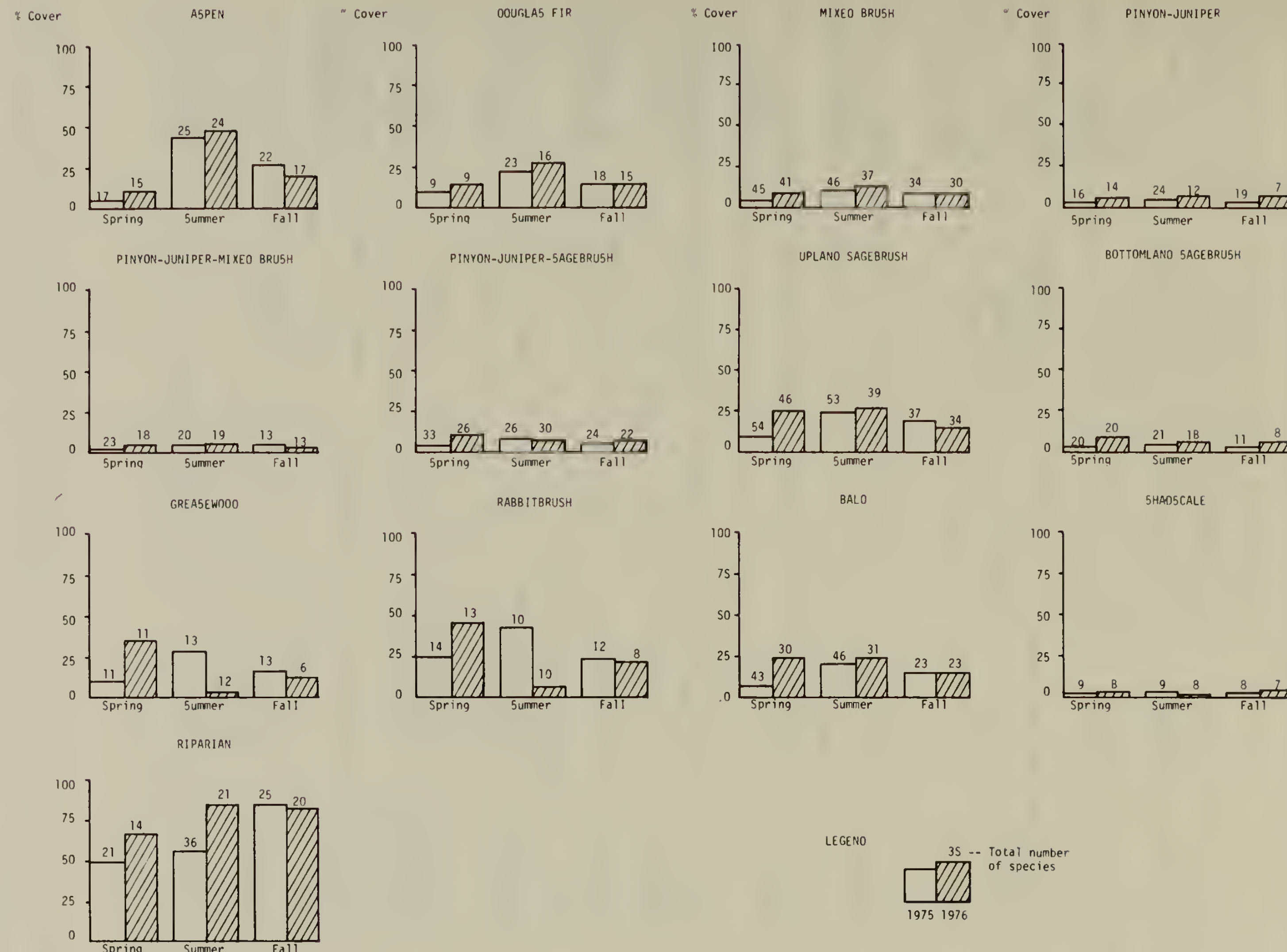


FIGURE 3.2
COVER AND DIVERSITY OF HERBACEOUS SPECIES SAMPLED ON PERMANENT TRANSECTS IN VEGETATION TYPES AND ASSOCIATIONS IDENTIFIED FOR RBOSP, 1975-1976.

TABLE 3.9

GENERAL INFORMATION REGARDING VEGETATION TYPES AND ASSOCIATIONS SAMPLED IN THE TRACT C-a VICINITY DURING 1974-1976 FOR RBOSP

Vegetation Type	Elevation	Exposure	Extent in Study Area	Soil Condition	Dominant Species
Aspen	2435 m (8,000 ft)	north- and east facing	961 acres (<1%)	deep, sandy loams with large accumulations of organic matter	serviceberry sp elk sedge
Douglas-Fir	2380 m (7,800 ft)	north- and east facing	1,598 acres (1%)	shallow soils	Douglas-fir serviceberry snowberry elk sedge
Mixed brush	2100-2250 m (7,000-8,500 ft)	all slope aspects	27,388 acres (25%)	deep, sandy loams and shallow soils above shale outcroppings	Utah serviceberry big sagebrush elk sedge
Pinyon-juniper woodland	1950-2250 m (6,500-7,500 ft)	all slope aspects	621 acres (<1%)	Rentsac soil series	pinyon juniper sandberg bluegrass slender wheatgrass
Pinyon-juniper mixed brush	2100-2250 m (7,000-7,500 ft)	north- and south facing	24,258 acres (22%)	Rentsac soil series	pinyon juniper Utah serviceberry big sagebrush sandberg bluegrass
Pinyon-juniper sagebrush	1950-2250 m (6,500-7,500 ft)	all slope aspects	20,288 acres (18%)	Rentsac soil series	juniper pinyon big sagebrush sandbergh bluegrass slender wheatgrass
Sagebush upland	1950-2550 m (6,500-8,500 ft)	all slope aspects	21,527 acres (20%)	Rentsac, Piceance, and Yamac soils series	big sagebrush Douglas rabbitbrush sandberg bluegrass Hood phlox
Sagebrush bottomland	1950-2550 m (6,500-8,500 ft)	all slope aspects	7,262 acres (7%)	Glendive soil series	big sagebrush Douglas rabbitbrush western wheatgrass Great Basin wildrye
Sagebrush greasewood	1950-2550 m (6,500-8,500 ft)	slope aspects characteristic of study area drainages	1,087 acres (1%)	alluvial soils	greasewood big sagebrush rubber rabbitbrush cheatgrass goosefoot
Sagebrush rabbitbrush	1950-2550 m (6,500-8,500 ft)	slope aspects characteristic of study area drainages	679 acres (<1%)	alluvial soils	rabbitbrush Great Basin wildrye goosefoot cheatgrass
Bald	2170-2565 m (7,230-8,550 ft)	west facing	2,087 acres (2%)	Rentsac soil series	Utah serviceberry green rabbitbrush sandberg bluegrass slender wheatgrass prairie junegrass
Shadscale	1938-2045 m (6,460-6,810)	steep south facing slope adjacent to major drainages	1,280 acres (1%)	rock outcrops or very shallow soils	shadscale big sagebrush criogonum fringed sagewort
Riparian	1950-2250 m (6,500-7,500 ft)	all slope aspects	185 acres (<1%)	wet	big sagebrush water birch quackgrass Kentucky bluegrass

trees, was found at low and intermediate elevations between 1950 and 2250 m (6500-7500 feet) on areas with shallow soils. The sagebrush types, dominated by big sagebrush shrubs, was found at all elevations within the study area, but predominantly on gently sloping uplands with deeper soils, and on alluvial soils along drainages. The rabbitbrush association represents a seral stage in the sagebrush type, and the greasewood association appears to be an edaphic variant of the sagebrush type within the study area. The shadscale shrub type is restricted to shale outcroppings on steep slopes along major drainages. The bald type consisting primarily of herbaceous species is restricted to windy ridgetops with shallow soils. The riparian type is limited to areas below the outflow of perennial springs along the major drainages, and consists primarily of introduced weeds and pasture grass species.

The flora identified in the Tract C-a study during 1974-1976 includes six tree species, 29 shrub species, and 186 herbaceous species, of which 45 species are classified as grass or grass-like. A species list was attached to the RBOSP Terrestrial Annual Report (1976) which included all species collected through 1975. Three species included in the flora require special notation. A milkvetch, Astragalus lutosus, formerly on the endangered plant species list (Smithsonian Institution 1975) and was located near cottonwood Springs on Big Duck Creek. A columbine (Aquilegia barnebyi), endemic to the Green River formation (Munz 1949), was located near Cottonwood Springs on Big Duck Creek. Colorado columbine (Aquilegia caerulea), the Colorado state flower, was located in most of the aspen (Populus tremuloides) stands and some of the more mesic mixed brush and Douglas-fir (Pseudotsuga menziesii) stands near Cathedral Bluffs. Of the 231 species identified, 15 were species introduced from outside North America. Vegetation studies on Tract C-b indicated that exotics contributed 16 percent of the flora identified in that study area (C-b Shale Oil Project 1976). Nearly all adventive species were herbaceous, with the exception of tamarix (Tamarix pentandra), a phreatophytic (water-loving) shrub.

Two years of baseline studies on the Tract C-a study area indicate that the plant communities present consist of a stable mosaic and are segregated from each other on the basis of the adaptation of the dominant species to different

environmental gradients imposed by the diverse topography and climatic variabilities of the study site. The controlling factor for plant distribution in the study area is topography (slope, aspect, angle, elevation) which influences moisture availability to the soil. Physical and chemical characteristics of the soil, in the study area as well as soil depth also have a very important effect on the distribution and abundance of different plant species. Another factor is the interaction between components of different strata within each vegetation type (tree, shrub, herbaceous). This interaction is particularly important in the pinyon-juniper and sagebrush types where the dominant overstory stratum exerts a major influence on the development of the understory strata. A third factor is the effect of destruction of different members of the plant community by fire, disease, and mechanical removal by man. These disturbances provide insights into the recovery or successional processes within a plant community. Whenever such disturbances could be found, the composition and age of the dominant plant species were examined to estimate future trends within the plant community. As indicated throughout this discussion, areas which were perceptibly changing over short periods of time were very rare, and small in size supporting the conclusion that plant communities within the study area are generally stable in their distribution and composition.

This conclusion does not discount short term changes in herbaceous cover and diversity which are responses to yearly climatic variability, and variable consumption by herbivores. For example, it was observed that herbaceous cover was generally lower for the spring of 1975 in permanent quadrats as compared to spring of 1976 (Figure 3.2). This lower cover was attributed to a much colder spring during 1975 than during 1976. It was observed that cover in rabbitbrush stands was much lower during the summer of 1976 than 1975, which appeared to be the result of differential livestock grazing. A major late freeze in 1976 which severely killed back Gambel oak, and damaged other shrub species and herbs provided an unusual opportunity to observe what may be a major limiting factor in the distribution of some species in the Piceance Creek basin.

The tree life form is considered the most conservative life form, requiring adequate precipitation for extensive development. The general scarcity of large trees within the study area indicated that the climatic conditions for optimum

tree growth are generally not met within this region. However, the pinyon-juniper type represents a stable adaptation to this climatic regime, and represents a complex of critical importance to animals living within the study area by providing shelter, and a major winter food source in the form of foliage, juniper berries, and pinyon nuts.

The shrub life form is the predominant life form in the study area and is best represented by big sagebrush, a species which is found at all elevations and on nearly all sites. Shrub species on the study area form an interactive group with nearly all sites containing more than one species. The reproductive strategy of shrub species appears to be divided between species which reproduce primarily by seeds, such as big sagebrush, greasewood, and rabbitbrush, and those which appear to reproduce primarily by vegetative means, and secondarily by seeds. This group includes serviceberry, chokecherry, and Gambel oak. Shrubs provide shelter and nesting sites for birds and small mammals, and provide a major portion of the diet of mule deer.

The herbaceous stratum over the study area is predominantly composed of perennial species, some of which are widely distributed throughout the study area at all elevations. Examples of widely distributed species include bladderpod (*Physaria floribunda*), Sandberg bluegrass, and slender wheatgrass. In general there is little change in herbaceous cover over the growing season due to the slow growth of most species. Exceptions to this generalization occur within the aspen and Douglas-fir types which contain species which sprout from dormant crowns each spring, and in greasewood and riparian areas where higher soil moisture levels permit more rapid plant growth. It was observed that all well-developed shrub stratum results in the primary dominance of only one or two species in the herbaceous stratum. Examples of shrub-herbaceous pairs are rabbitbrush-Great Basin wildrye, and mixed brush-elk sedge. Maximum herbaceous stratum diversity appears to occur primarily in open areas such as balds.

The aspen and Douglas-fir types occur at the highest elevations (above 2250 m, 7500 feet), on portions of the study area and are a minor component of the

Tract C-a ecosystem because of their limited areal extent and distribution, but are the most structurally diverse, most productive, and provide the greatest standing crop among the vegetation types identified on the study area.

These conclusions are based on the presence of a dense tall tree stratum and a dense and diverse shrub and herbaceous strata which contribute to high annual production and standing crop. The high productivity of these sites appears to result from favorable growth conditions resulting from sustained periods of high soil moisture. These favorable soil moisture conditions within aspen and Douglas-fir stands appear to be the result of deep winter snow, from reduced solar radiation because of the location of these types on north-facing slopes, and from generally deep loamy soils. The aspen and Douglas-fir types appear to be segregated from each other on the basis of shallower soils in the Douglas-fir stands, and do not show evidence of seral interrelationships on the study area. The relatively moist cool conditions sustain several species of plants and animals not found elsewhere on the study area. The structural diversity and abundant food sources within these types contribute to the high summer diversity of birds, and frequent utilization of these areas by mule deer and elk. Animal utilization of these types during the winter is limited because of deep snow cover.

No human disturbance was noted in any Douglas-fir or aspen stands on the study area. This lack of activity is probably due to the inaccessibility and small size of these stands, limiting their economic importance.

The sagebrush, mixed brush, and pinyon-juniper types form an interactive mosaic over the entire study area, and are the dominant vegetation types based on areal extent. These three types appear to be segregated from each other on the basis of climatic, edaphic, and biotic factors. The mixed brush type is found primarily at higher elevations (above 2100 m, 7000 feet); the pinyon-juniper type is found at intermediate and lower elevations (below 2250 m, 7500 feet); the sagebrush type is found at all elevations, but is most common at lower elevations (below 2100 m, 7000 feet) The three types intergrade extensively at intermediate elevations within the pinyon-juniper type, forming broad ecotonal areas with compositional and structural characteristics of all three types. These ecotonal areas have been segregated in this study by dividing the pinyon-juniper

type into three associations, based upon the cover and composition of the shrub understory. Sagebrush predominates on areas with relatively deep soils, particularly along the tops of ridges and the bottoms of drainages; pinyon-juniper and mixed brush predominate on shallow soils at intermediate elevations on the study area, and tall mixed brush species such as serviceberry and Gambel oak increase in importance on deeper soils at higher elevations where precipitation is higher and overall temperatures are cooler.

The sagebrush type was divided into four associations based on edaphic, physiognomic, and seral criteria. Upland sagebrush was segregated from bottomland sagebrush on the basis of differences in height and density, and occurrence on different soil types (bottomland on alluvial, upland on residual soils). The greasewood association was designated as an edaphic variant of the bottomland sagebrush association based on its occurrence on soils with high salinity or alkalinity; the rabbitbrush association was considered a seral variant of the bottomland sagebrush association because of its secondary successional status on disturbed bottomland sagebrush sites.

Relative production within the three types appears to be primarily controlled by available soil moisture. Production appears to generally increase with elevation in the study area, suggesting a gradient of greater precipitation with elevation. Upland sagebrush and mixed brush stands above 2100 m (7000 feet) appear to be more productive than pinyon-juniper and sagebrush stands below this elevation. However, relatively high production was also noted in low elevation bottomland sagebrush, greasewood, and rabbitbrush stands, where it appeared that perennial subsurface moisture contributed to rapid growth. In the pinyon-juniper type, the tree stratum contributed the majority of the annual production because of the capability of pinyon pine and Utah juniper to out-compete other plant species for available water. Production in the pinyon-juniper type was also assumed to be low because of generally shallow soils with limited water-holding capacity (RBOSP 1976).

The physiognomy and species composition of the different types influence the type of animal usage presently occurring. An extensive and diverse herbaceous component exists in both the mixed brush and the sagebrush type, and large

herbivores are most frequent in these types. Shrub species occurring in these two types are also important browse species for mule deer. The pinyon-juniper type, because of the reduced importance of the shrub and herbaceous strata (due to dominance by the mature trees) is most important in terms of the utilization of these dominant tree species in the form of nuts and juniper berries for birds and rodents, and as browse and shelter for large mammals. Differences in species composition among the upland, bottomland, rabbitbrush, sagebrush, and greasewood associations is believed to affect the types of animals which occur within the different associations. The herbaceous stratum of the greasewood, rabbitbrush, and bottomland sagebrush associations consists of a number of annual species which, because of their high seed production, favor the occurrence of seed eating small mammals and birds. The greater cover afforded by the shrub stratum in these associations also appears to favor large populations of small mammals, making these bottomland habitats especially important to the Tract C-a ecosystem. The upland sagebrush stands consist of a larger component of grass species, and shrub cover is less. Small mammals and birds were found to be less abundant in these sites, but these areas were heavily utilized by livestock and wild horses.

Human activity within these three types was minor. The major evidence of human disturbance was the development of fields and pastures along the bottom of major drainages within the bottomland sagebrush association. Many of these fields were abandoned, and are currently undergoing secondary succession. Some of these pasture areas are maintained for livestock, resulting in continued disturbance of the plant community in the vicinity of perennial sources of water.

The shadscale type is an edaphically and topographically determined type which occurs in local areas along the face of steep south-facing slopes in the major drainages. It occurs in transitional areas between bottomland sagebrush stands and pinyon-juniper woodlands, and shares species common to both of these plant communities. The areal extent of the shadscale type is very small and the production and biomass of the dominant species, consisting of shadscale and big sagebrush, is very low. The importance of this type to the Tract C-a ecosystem is minor because of its low productivity.

The bald type is also an edaphically and topographically determined type occur-

ring in local areas on tops of ridges where strong winds and shallow soils occur. Composition of these areas is restricted primarily to mat-forming herbaceous species. Shrubs and trees appear to be unable to establish themselves in these areas. Despite the severe conditions, herbaceous productivity is similar to nearby sagebrush stands. The balds are critical winter habitat for wild horses to feed during winter. Utilization of these areas by small mammals and birds is low because of low cover and low food availability.

The riparian type occurs as isolated areas in the bottom of major drainages where perennial water flows. These areas have been extensively developed as livestock pastures, and species composition consists largely of introduced grasses and forbs. These sites are unusual because of the general absence of shrub and tree species characteristic of riparian habitats in western Colorado, such as willows and cottonwood trees. One spring area, Cottonwood Spring on Duck Creek, is relatively undisturbed, and contains several plant species which are unusual within the Piceance basin. Riparian areas are highly productive because of abundant moisture and are heavily utilized by livestock.

CHAPTER 3 - HABITAT ANALYSIS

Soil and vegetation interact to provide habitat for fauna. Since the soil and vegetation complex forms the principal focus of many food chains, understanding the interrelationships that exist between these components is important. Data analyses were performed to attempt to identify important factors which are critical to the function of the soils-vegetation system and to further quantify the structure of the system thus, permitting more representative sampling during oil shale development. Description of these interrelationships should enable an ecologist to better manage the system (e.g., grazing use), to predict perturbations, and to suggest mitigative measures to minimize adverse impacts on the system.

The interrelationships of soil and vegetation are presented in this chapter to provide a preliminary understanding of the dynamics of the existing faunal habitats on Tract C-a. The relationships of the animal species and their habitats are discussed in Chapter 4.

The specific objectives of the analyses of soils and vegetation data were to determine:

- Similarity between vegetation sampling locations and between soil sampling locations
- Apparent links between various soil traits
- Which soil variables or principal components determine or account for the major variability within the system
- Significant interrelationships between vegetation and abiotic factors.

The results of the data analyses are discussed below. These analyses have been used to develop a practical, statistically sound program for detecting major impacts resulting from oil shale development.

I. Soils

Soils were analyzed by performing a principal component analysis and a hierarchial cluster analysis. These analyses do not test a specific hypothesis, but rather determine patterns within a complex data set. The objective of these analyses was to detect interrelationships among the 46 soil variables analyzed within 352 samples. A detailed explanation of soil sampling and analysis methodology is presented in Chapter 1 of this section. For the purposes of discussion, soil variables are grouped into general soil properties, organic matter, gypsum, macronutrients, micronutrients, trace elements, radioactivity, water-holding capacity, and particle size. Table 3.10 lists the variables and their abbreviations for each category. Summary tables of the analyses are provided here, for discussion; data sets are presented in RBOSP Progress Report 10 (1977).

A. Principal Component Analysis

Principal component analyses is a method to organize correlations or interrelationships by positing that there are underlying components which make up the interrelated soil factors (Davis 1973; Comrey 1973; Blackith & Reyment 1971) The initial factor method: principal axis was used to generate a correlation matrix (standardized variances = one on the diagonal; covariances on the off diagonals) (Clifford & Stephenson 1975); eigenvalues for all 46 variables and the proportion of the variance they contribute; eigenvectors for 11 retained factors and their factor patterns; and final communality estimates for each variable of the 11 factors.

Most, but not all, of the soils data are in parts per million, and were standardized to a zero mean with units of ± one standard deviation (Davis 1973; Clifford & Stephenson 1975). This standardization was necessary to compare variables with different units and to insure that every variable influenced the analysis in direct proportion to its variance. Factors can be rotated to positions in which they are not necessarily orthogonal. Orthogonal solutions are those in which the factors are uncorrelated. Criteria for carry-

TABLE 3.10

ABBREVIATIONS OF SOIL PROPERTIES DELINEATED BY GROUP

Group	Soil Property	Abbreviation
General Soil Properties	Depth	Depth
	pH measured in H_2O	pH (H_2O)
	pH measured in CaCl	pH ($CaCl_2$)
	Electrical conductivity	E Cond
	Adjusted conductivity	AJ Cond
	Sodium measured in H_2O	Na(H_2O)
	Cation capacity	Cat Cap
	Exchangeable sodium percentage	Ex Na P
Macronutrients	Ammonium	NH_3
	Nitrate	NO_3
	Extractable phosphate	PO_4-Ex
	Available Potassium	K-aval
	Magnesium measured in water	Mg(H_2O)
	Calcium measured in water	Ca(H_2O)
	Potassium measured in water	K(H_2O)
	Sulfate measured in water	SO_4(H_2O)
Micronutrients	Boron measured in water	Bo(H_2O)
	Copper measured in DTPA	Cu(DTPA)
	Manganese measured in DTPA	Mn(DTPA)
	Iron measured in DTPA	Fe(DTPA)
	Zinc measured in DTPA	Zn(DTPA)
	Molybdenum extracted	Mo Ext
Organic Matter	Organic matter	Org Mat
Gypsum	Gypsum	Gypsum
	Lime requirement	TPO_4
Trace Elements	Arsenic	As
	Chlorine	Cl
	Chromium	Cr
	Cobalt	Co
	Fluorine	Fl
	Mercury	Hg
	Antimony	SB
	Vanadium	V
	Selenium	Se
	Nickel measured in NH_3	Ni(NH_3)
	Lead measured in NH_3	Pb(NH_3)
Radioactivity	Uranium, Total	U
	Equivalent Uranium	Eq U
	Equivalent Thorium	Hot K
	Radium	Ra
Water-Holding Capacity	1/3 Bar Water-Holding Capacity	Bl-3 H_2O
	15 Bar Water-Holding Capacity	B-15 H_2O
Particle Size	Sand	Sand
	Silt	Silt
	Clay	Clay

ing out these rotations to non-orthogonal positions are often difficult to establish (Blackwith & Reyment 1971; Davis 1973) and, in lieu of these criteria, the soils data were not rotated. The methods of factor extraction used here extracted as much variance as possible from each successive factor (Davis 1973). Factor size decreased from the first to the last factor and, in general, the largest variances were associated with the first and second principal components.

The correlation matrix indicated substantial correlations between variables (Table 3.11) which were related to each other or overlapped what they measured (Comrey 1973). The soils data had many significant ($P \leq 0.05$) correlations i.e., significantly different from zero. Most correlation coefficients were less than 0.5, reflecting relatively weak relationships between variables.

Several patterns emerged from the correlation matrix:

1) Correlations between general soil properties were significant except that electrical conductivity did not correlate with depth, pH(H_2O), or cation capacity.

2) Across variables, organic matter significantly correlated with all seven general soil properties except conductivity or Na(H_2O); with three (Mn, Zn, Mo) of the five micronutrients; and with particle size (positive correlation with both silt and clay, negative correlation with sand).

3) Radioactivity was not significantly correlated with any variable in the macro-or micronutrients, organic matter, gypsum, or water-holding capacity groups.

4) Only general soil properties had a large fraction of significant correlations among the variables (33 of the 36 pair-wise combinations) but of the eight general properties only electrical conductivity showed no significant correlation with depth.

5) None of the trace elements were correlated with depth, nor were radioactivity,water-holding capacity, or particle size.

The analysis of soils on Tract C-a indicated that there were a large number

TABLE 3.11

CORRELATION COEFFICIENTS[1] BETWEEN SOIL CHARACTERISTICS
FOR RBOSP TRACT C-a

Soil Variables	Correlation Coefficient
AJ Cond - E Cond	.95
Silt - Sand	-.93
Na (NH_3) - Na (H_2O)	.89
Na (H_2O) - AJ Cond	.88
Na (H_2O) - E Cond	.86
SO_4 (H_2O) - E Cond	.85
Ex Na P - Na (NH_3)	.85
Rad - Eq U	.84
Sand -B 1-3 (H_2O)	-.84
B - 15 (H_2O) - B 1-3 (H_2O)	.83
Silt - B-1-3 H_2O	.78
SO (H_2O) - Mg(H_2O)	.78
SO (H_2O) - Ca(H_2O)	.77
Ca (H_2O) - Mg (H_2O)	.76
SO (H_2O) - Na (H_2O)	.76
Na(NH_3) - AJ Cond	.73
Mg(H_2O) - E Cond	.72
Na(NH_3) - E Cond	.71
Ex Na P - ph (H_2O)	.70
Clay - Sand	-.68
Sand - B 15 (H_2O)	-.68
Se - Mg (H_2O)	.66
K(H_2O) - K-Aval	.66
Ca(H_2O) - E Cond	.64
Mg(H_2O) - AJ Cond	.64
B-15 H_2O - Cat Cap	.63
Org Mat - Cat Cap	.62
K(H_2O) - Mg(H_2O)	.62
Se - K(H_2O)	.62
B - 15 (H_2O) - Org Mat	.62
Ca (H_2O) - AJ Cond	.61
Clay - B1-3 H_2O	.60
Clay - B15 (H_2O)	.60

1/ Coefficients greater than .6 have been included.

of significant but low correlations and that 22 factors were required to account for 90 percent of the variance in this multi-variate data. The first two factors only accounted for 32 percent of its variance. If there were only high positive correlations, these soil data would probably have fallen into one or two principal components. However, with both low correlations and negative correlations, more than two factors were needed to account for the inter-correlations found in the correlation matrix (Davis 1973; Comrey 1973).

The initial factor method in this analysis retained all factors which had eigen-values greater than one (e.g., variance is greater than the original standardized variables) (Davis 1973). Eleven eigen factors were retained and analyzed in this factor pattern. The factor pattern resulted from extraction of factors from the correlation until all variance had been accounted for. The resulting pattern of 11 factors consisted of numbers of "loadings" which represented the extent to which the variables were related to the hypothetical "factor" (Comrey 1973) i.e., correlations between the particular variable. The factor pattern generated from the RBOSP soils data included 11 factors which accounted for ap-roximately 75 percent of the variation (Table 3.12). The soil variables which contribute to each factor are discussed below.

I) Factor I accounted for only 17 percent of the total variance. The first two factors (eigenvectors) accounted for 32 percent of the total variance in the soils data set. The variance represented in Factor I was contributed by the general soils properties, particularly pH, conductivity, Na, cation capa-city, and exchangeable Na-P. Four macronutrients (NH_3, Mg, Ca, SO_4) and the three particle sizes had high loadings in this first factor. This corresponds to the correlation matrix, where the general soil properties had the most significant cross-correlations of all soil groups.

II) The second component (15 percent of the total variance) included macro-nutrients (seven of eight) micronutrients (four of six), trace elements, water-holding capacity, and particle size (positive for silt and clay, negative for sand).

TABLE 3.12

PATTERN OF 11 FACTORS WITH EIGENVALUES GREATER THAN ONE

	Factor											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII-XXII
Variance Portion (%)	17	15	10	7	5	5	4	3	3	3	2	16
General Soil Properties												
Depth	.46		-.41									
pH(H_2O)	.60				.31							
pH($CaCl_2$)	.67		-.33			.31						
E Cond	.69	.61										
AJ Cond	.75	.50										
Na(H_2O)	.73	.44										
Na(NH_3)	.81											
Cat Cap	-.70											
Ex Na P	.72				.34	.31						
Macronutrients	.30											
NH_3	.34	.36										
NO_3								-.30		-.47	-.35	
PO_4-Ex		.34	.43			.40						
K-aval		.39	.58		.30							
Mg(H_2O)	.45	.64				-.34						
Ca(H_2O)	.40	.59			-.31	-.32						
K(H_2O)		.60	.46									
SO_4(H_2O)	.62	.61										
Micronutrients						.43						
Bo(H_2O)		.31							.35			
Cu(DTPA)		.46	-.42	.33								
Mn(DTPA)	-.35		.60					.30				
Fe(DTPA)			.52	.40				.41	-.43			
Zn(DTPA)		.42	.56						-.42			
Mo(DTPA)		.63										
Organic Matter	-.56	.45										
Gypsum				.34	.47							
Trace Elements							-.42			.39		
TPO_4												
As		.35	-.47									
Cl	.39											
Cr			.35	.49								
Co				.64	-.35							

TABLE 3.12 (Continued)

	Factor											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII-XXII
Fl		.42	-.54									
Hg			-.39		-.43	.42						
SB				.48								
V		.37		.61	-.30					.32		
Se	.35	.51							-.33			
Ni-NH		.48					-.36	.56				
PB-NH		.42		.53	-.30							
Radioactivity												
U										.48		
Eq-U			-.38		.32		.64					
HotK				.44					.43			
Ra			-.37		.37		.61					
H_2O-Holding Capacity												
B-1-3 H_2O	.50	.60	-.33									
B-15 H_2O	-.60	.57										
Particle Size												
Sand	.47	-.60	.39									
Silt	-.37	.57	-.41									
Clay	-.48	.38										

III) Factor III (10 percent of the total variance) included four (Cu, Mn, Fe, Zn) of the six micronutrients, negative loading for three (As, Fl, Hg) trace elements, and two (Eq-U, Ra) radioactivity measures.

IV-V) Factor IV (7 percent of the total variance) had positive loadings with five of the 12 trace elements, and had negative loadings with four trace elements.

VI-XI) Interpreting the loading patterns became difficult after the first five factors, since few loadings were above .30. It was therefore, difficult to detect meaningful patterns from the low loadings scattered among the soil variables.

Communality represents the degree of overlap between a variable and the 11 factors. Communality (h^2) of one indicates that the variable overlapped completely for the initial 46 factors (Davis 1973). As additional factors were extracted the communalities became less, providing an estimate of the efficiency of the reduced set of factors (Comrey 1973). If a variable has an $h^2 = 0$, the loadings for the variable would be zero for all 11 extracted factors. The variable would then share nothing in common among the 11 factors.

The general soil properties, water-holding capacity and particle size categories had among the highest communalities (Table 3.13) across the 11 factors. Electrical conductivity and Na-NH_3 had the highest communalities (.93) and both had high loadings in the first two factors (.69, .81) (Table 3.12).

The lowest communalities, NH_3 (.43) and U (.45) were reflected in the low loadings for these variables (NH_3: I= .34, II= .36; U:X = .48).

B. Cluster Analysis

Cluster analysis organizes variables into more or less homogeneous groups or clusters and indicates the relationships within and between these groups (Sneath & Sokal 1973). Soil samples identified as vegetation type and soil series were clustered within three locations: Tract C-a, 84 Mesa, and off-

TABLE 3.13

COMMUNALITY VALUES FOR SOIL VARIABLES OVER 11 FACTORS

General Soil Properties		Macronutrients		Micronutrients		Organic Matter Gypsum		Trace Elements		Radioactivity		H_2O-Holding Capacity		Particle Size	
Oepth	.54	NH_3	.43	Bo(H_2O)	.56	Organic Matter	.77	TPO_4	.58	U	.45	Bl-3 H_2O	.87	Sand	.92
Ph(H_2O)	.83	NO_3	.51	Cu(OTPA)	.69	Gypsum	.60	As	.59	Eg-U	.88	B-15 H_2O	.79	Silt	.81
pH($CaCl_2$)	.76	PO_4-Ex	.67	Mn(DTPA)	.73			Cl	.46	Ho+K	.57			Clay	.71
E-cond	.93	K-Aval	.72	Fe(DTPA)	.82			Cr	.63	Ra	.84				
AJ-cond	.90	Mg (H_2O)	.86	Zn(DTPA)	.77			Co	.66						
Na-(H_2O)	.90	Ca (H_2O)	.83	Mo(DTPA)	.60			Fe	.70						
Na-(NH_3)	.93	K(H_2O)	.85					Hg	.68						
Cat-Cap	.85	SO_4 (H_2O)	.89					Sb	.64						
Ex Na P	.84							V	.77						
								Se	.70						
								Ni(NH_3)	.82						
								Pb(NH_3)	.74						

tract areas other than 84 Mesa. The soil samples were clustered on the basis of similarities of 46 soil characteristics categorized into the groups described earlier.

The cluster technique used was an agglomerative, single link method (Aaker 1971; Johnson 1967) which grouped samples into fewer and fewer clusters, by a single similarity between an existing group and one other soil sample. Starting with 132 clusters (one soil sample each), the technique selected one cluster to be combined with another to make 131 clusters. To do this, a simple matching coefficient was calculated between each of the 132 initial clusters; this coefficient was based on the number of similar soil characters. Matching coefficients could range from zero to one and the largest similarity element was identified at each step. This agglomerative process was repeated until all samples were grouped into a single cluster (Clifford & Stephenson 1975).

For the present analysis, five clusters were used to compare the soil characteristics of the three locations. Distances within and between clusters, average values for each soil characteristic, and cluster listings were determined for each soil characteristic for each of the five clusters. Because the cluster analyses identified vegetation types or soil series that were similar with respect to 46 soil characteristics, the resulting clusters have the same degree of internal (within cluster or 'maximum' distance) homogeneity and the same degree of external (between cluster or 'minimum' distance) heterogeneity. In other words, the soil characteristics are grouped into identical clusters but they are identified by vegetation or soil type. The clustering of soil characteristics was done for three locations and each will be discussed separately.

1. Tract C-a

Distances between and within the five clusters are listed in Table 3.14. For Tract C-a, the smallest of the maximum distances were in Cluster III (which had only two vegetation types), Cluster IV with four vegetation types, and Cluster II with four samples. Cluster V had a relatively large maximum distance indicating that the two pinyon-juniper samples in it were widely spaced in their similarities over soil characteristics. In comparison, Cluster

TABLE 3.14

DISTANCE WITHIN AND BETWEEN FIVE CLUSTER FOR TRACT C-a, 84 MESA, AND OFF-TRACT AREAS

	Cluster	No. Sample Points	Distance Within		Between Clusters V	IV	III	II	I
Tract C-a	V	5	2.1	V	0				
	IV	4	1.6	IV	1.4	0			
	III	2	0.6	III	6.4	0.9	0		
	II	4	1.8	II	13.4	5.1	4.3	0	
	I	120	3.3	I	12.4	2.8	1.3	1.5	0
		135							
84 Mesa	V	1	0	V	0				
	IV	4	0.5	IV	.8	0			
	III	5	1.3	III	1.4	0.5	0		
	II	2	0.2	II	4.9	5.3	1.0	0	
	I	27	1.5	I	3.6	3.3	0.5	0.2	0
		39							
Off-Tract Area	V	1	0	V	0				
	IV	1	0	IV	30.2	0			
	III	6	5.2	III	20.7	2.1	0		
	II	4	2.7	II	33.6	6.6	0.7	0	
	I	129	3.9	I	38.9	3.2	0.6	0.6	0
		141							

I had 120 sampling points and a relatively strong clustering. Clusters I and II had the smallest distance (0.15) between clusters indicating that they were the most similar of the five clusters retained. Cluster III, which contained two pinyon-juniper samples, was more distant or dissimilar than Clusters II and III.

Table 3.15 lists the relative proportion of each vegetation and soil type within each of the five clusters for each of three locations. For Tract C-a, most vegetation types in Cluster I (120 samples) were sagebrush (46 percent) and pinyon-juniper (34 percent) with few rabbitbrush or shadscale. Two clusters represented single vegetation types. Cluster III was sagebrush and Cluster V was pinyon-juniper. The remaining Clusters (II & IV) had sample points from sagebrush but apparently they were sufficiently different to be separated into distinct clusters. Obviously, Clusters III and V, each with two sample points, were most homogeneous. Cluster 1 represented the greatest number of vegetation types i.e., sagebrush, pinyon-juniper, mixed brush, rabbitbrush, and shadscale.

Cluster I, because it contained almost 90 percent of the samples, included all the soil series including the Redcreek, Rentsac, and Rivra series. Cluster III contained only the Glendive series and Cluster V contained only the Torriorthent type.

Comparisons were made between the mean value for a given soil variable within each cluster and the average value for all samples collected in a general location (Table 3.16). (Anderberg 1973). Although deviations from the overall mean could not be quantified, deviations of two times the mean were defined as high (positive) and deviations of one-half the mean as low (negative). A summary of the number of variables in each cluster which deviated from the overall mean is presented in Table 3.17.

Clusters I and II had very few deviations from the average tract values. This would be expected since Cluster I contained almost 91 percent of the sample points from Tract C-a and therefore, strong deviations from the overall averages

TABLE 3.15

THE RELATIVE PROPORTION OF EACH VEGETATION OR SOIL TYPE INCLUDED IN FIVE CLUSTERS FOR TRACT C-a, 84 MESA, AND OFF-TRACT AREAS.

	Tract C-a					84 Mesa					Off-Tract C-a				
Clusters:	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
No. Sample Points:	(120)	(4)	(2)	(4)	(2)	(27)	(2)	(5)	(4)	(1)	(129)	(4)	(6)	(1)	(1)
Vegetation															
Sagebrush	46	75	100	75		100	100	100	100	100	40	50	33		
Pinyon-Juniper	34				100	22					28	25	33		
Mixed Brush	16	25									20				
Rabbitbrush	3														
Shadscale	4			25											
Aspen											4				
Greasewood											3				
Douglas fir											2				
Bald											2				
Riparian											<1				
Soil Types															
Torriorthent	5			75	100						2		16		
Glendive	25	25	100	25							13	50	16		
Redcreek	13										17	25	16		
Rentsac	41					11	50				17				
Piceance	14					63	50	100	100		6				
Rivra	3														
Vandemore											9				
Parachute											5				
Havre											9	25	50	100	100
Irigu											3				
Castner											8				
Yamac						26				100	12				

TABLE 3.16

MEAN VALUES FOR SOIL TRAITS FOR EACH CLUSTER AND THE OVERALL MEAN FOR THE GENERAL LOCATION

Soil Trait	Overall Mean	Tract C-a Cluster					Overall Mean	84 Mesa Cluster					Overall Mean	Off-Tract Cluster				
		I	II	III	IV	V		I	II	III	IV	V		I	II	III	IV	V
pH (H_2O)	8.3	8.3	8.3	8.4	8.1	9.2	8.8	8.8	8.5	.8.8	8.8	8.5	8.4	8.5	9.0	8.2	7.9	8.6
pH ($CaCl_2$)	7.9	7.8	8.0	8.3	7.9	8.9	7.9	7.9	7.7	8.0	8.3	8.1	7.8	7.7	8.3	8.0	7.8	8.5
E Cond	0.86	0.61	1.14	3.28	1.82	10.26	1.33	0.43	0.30	2.0	5.4	5.8	0.89	0.45	2.93	4.73	5.55	10.4
AJ Cond	3.2	2.6	4.1	9.1	5.6	44.2	5.7	2.1	1.5	12.2	21.5	29.6	3.5	2.0	11.6	19.0	20.0	39.4
Na(H_2O)	1.09	.72	1.41	3.07	1.60	18.99	1.83	.61	0.29	4.2	6.3	4.4	1.02	0.49	3.37	3.02	3.91	9.8
Na(NH_3)	2.82	2.31	3.9	4.9	3.03	27.8	4.39	2.62	2.30	8.2	10.1	6.7	2.87	2.06	9.85	6.17	6.5	12.1
Cat Cap	34.2	34.6	38.0	31.0	22.1	24.6	36.9	37.6	44.2	32.5	35.7	32.1	37.0	40.7	28.7	26.9	38.1	30.7
Ex Na P	5.1	6.0	7.1	6.2	6.8	37.7	6.9	6.5	4.6	11.3	11.0	7.0	5.0	5.6	25.7	11.9	6.8	7.5
NH_3	9.0	9.0	9.2	6.8	12.9	6.7	7.2	7.0	7.8	7.0	7.5	5.9	9.3	10.2	7.4	11.8	20.6	5.5
NO_3	10.5	9.9	11.0	2.0	5.1	50.1	4.6	4.5	1.7	0.6	11.3	1.2	6.3	2.8	2.4	6.4	8.0	3.4
PO_4-Ex	12.6	13.1	8.3	9.0	3.3	13.0	10.7	7.8	19.0	14.2	16.3	24.0	12.7	11.2	59.0	29.2	39.0	11.0
K-aval	262.1	266.5	180.	502.5	181.3	142.5	378.6	382.6	640.	334.	290.	350.	385.1	444.9	1869.	498.3	1640.	1150.
Mg(H_2O)	14.5	7.9	18.1	92.6	149.9	40.4	23.3	5.6	4.4	35.2	94.9	156.8	16.2	7.5	36.0	116.2	199.0	227.4
Ca(H_2O)	59.6	37.0	43.	228.	568.2	228.	88.5	32.4	39.0	102.1	378.8	363.	59.8	33.5	111.4	327.3	364.5	436.0
K(H_2O)	10.0	8.4	7.3	57.6	28.9	19.2	9.4	7.0	13.3	11.5	15.7	23.4	12.2	10.1	75.2	34.7	170.0	141.0
SO_4(H_2O)	302.8	150.3	330.5	1475.	2396.	3812.	691.1	226.9	377.5	1355.	2506.	2350.	323.2	116.6	659.5	1725.	1050.	6200.
Bo(H_2O)	0.7	0.67	.65	1.0	.7	1.1	0.5	0.5	0.5	0.6	0.5	0.5	0.6	0.6	0.9	0.8	1.1	0.8
Cu(DTPA)	2.1	2.0	3.0	2.1	1.9	4.2	1.4	1.4	1.6	1.4	1.2	1.2	1.8	1.6	1.6	1.4	1.8	2.2
Mu(DTPA)	30.2	31.5	24.8	18.	13.8	16.5	29.8	31.7	41.5	26.6	22.5	19.0	33.7	37.3	48.5	33.5	80.0	40.0
Fe(DTPA)	81.0	82.6	72.0	37.	55.	71.	112.9	100.7	160.0	142.8	117.0	102.	104.4	126.7	108.0	82.3	198.0	140.0
Zn(DTPA)	1.4	1.4	1.5	1.0	1.15	1.1	1.3	1.2	2.0	1.3	1.3	1.2	1.5	1.5	2.3	1.7	4.8	9.0
Mo Ext	0.3	.2	.5	1.1	0.9	0.7	0.27	0.24	0.40	0.30	0.38	0.3	0.3	0.3	0.9	0.6	0.6	1.2
Org Mat	3.1	3.1	2.8	2.7	1.6	0.8	1.6	1.8	4.1	0.9	1.0	0.7	2.9	3.1	4.9	3.1	8.1	2.4
Gypsum	0.3	0.3	0.4	0.2	0.2	1.2	0.3	0.3	0.2	0.5	0.2	0.2	0.4	0.4	1.6	0.2	0.2	0.2
TPO_4	0.	446.4	592.8	442.5	432.3	544.	0.	620.	1436.	756.	257.	618.	0.	591.6	681.0	673.2	670.0	641.0
As	10.0	9.5	23.8	10.0	11.3	10.0	6.8	6.3	7.5	6.0	6.3	20.0	8.4	7.7	5.0	6.7	5.0	5.0
Cl	1002.	954.	2075.	850.	1100.	1550.	754.1	659.	550.	940.	1225.	400.	910.0	831.8	1400.	1283.	1300.	1100.
Cr	44.0	44.	40.	45.	33.	48.	47.6	46.7	57.5	46.0	45.0	55.0	44.4	44.5	40.0	39.2	40.0	45.0
Co	7.0	7.0	8.8	7.0	6.3	9.5	9.6	9.3	11.5	10.2	9.5	10.0	8.0	8.4	8.5	7.8	9.0	8.0
Fl	596.5	584.	790.	720.	585.	630.	398.6	366.7	330.0	452.0	515.0	410.0	510.	467.2	425.0	480.0	390.0	260.0
Hg	24.0	22.9	33.8	12.5	28.8	42.5	12.7	10.7	10.0	14.0	23.8	16.0	18.8	15.8	18.8	16.7	20.0	15.0
SB	1.0	1.0	1.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.0	1.0	1.0	1.0
V	57.7	57.4	65.0	62.5	52.5	70.0	63.9	61.1	82.5	65.0	65.0	60.0	59.1	59.4	55.0	58.3	50.0	60.0
Se	34.1	23.8	32.5	250.	60.	395.	18.6	15.6	10.0	24.0	35.0	28.0	56.4	23.5	27.5	706.9	2400.	2600.
Ni(NH_3)	0.7	0.6	0.8	0.8	2.0	1.6	0.9	0.9	0.8	0.9	1.3	1.0	0.9	0.9	1.3	1.3	1.2	1.2
Pb(NH_3)	1.6	1.5	1.6	1.6	3.4	1.8	1.0	0.9	1.1	6.9	1.3	1.1	1.4	1.2	2.0	2.0	2.0	1.8
U	2.3	2.3	2.5	2.5	3.0	2.0	2.2	2.1	2.0	2.6	2.5	2.0	2.2	2.2	2.0	2.0	2.0	2.0
Eq U	2.9	2.9	4.0	3.0	2.3	3.5	2.8	2.7	2.5	3.4	3.0	3.0	2.7	2.5	2.0	2.7	1.0	3.0
Hot K	9.4	2.4	2.1	2.4	2.6	4.0	11.8	2.5	2.9	2.7	2.6	2.0	10.5	2.54	2.12	2.30	2.3	2.4
Ra	1.0	1.0	1.1	1.0	0.6	1.3	1.0	0.9	1.0	1.1	1.0	1.0	0.9	0.8	0.6	0.9	0.5	1.0
B1-3 H_2O)	26.9	26.4	31.2	36.2	30.2	25.1	23.2	23.1	21.0	23.5	25.1	19.6	25.7	25.3	25.2	26.2	27.8	26.4
B-15 H_2O)	13.0	12.8	15.6	14.4	13.7	9.7	10.9	10.9	11.4	10.6	11.2	7.6	12.6	12.6	13.3	13.1	14.6	12.4
Sand	36.5	37.2	28.8	21.0	31.8	29.3	40.4	40.0	48.5	38.8	35.0	55.0	39.1	41.5	42.9	41.1	46.0	24.0
Silt	50.3	49.6	55.9	61.0	60.5	61.0	42.9	42.5	31.3	40.7	49.4	32.0	47.0	44.6	44.8	46.8	41.5	60.0
Clay	13.2	13.2	15.4	18.0	7.8	9.8	16.7	16.2	20.3	20.5	15.6	13.0	13.9	13.9	12.4	12.2	12.5	16.0

TABLE 3.17

A SUMMARY OF DEVIATIONS OF CLUSTER MEAN VALUE FOR SOIL TRAITS FROM THE OVERALL MEAN FOR A GENERAL LOCATION

	Tract C-a					84 Mesa					Off-Tract Areas				
Cluster	V	IV	III	II	I	V	IV	III	II	I	V	IV	III	II	I
Soil Traits															
General Soil Properties(8)	1- ,6+	1-,1+	2+	1+		2+	3+	3+	3-	3-	4+	4+	5+	4+	1-
Macronutrients(8)	1-,4+	3-,5+	1-,5+	2-	2-	1-,4+	4+	1-,5+	4-,1+	3-	4+	6+	3+	2-,4+	3-
Micronutrients(6)			1-,1+	1-	1+						1+	1+			
Organic Matter (1)				1-	1-							1+			
Gypsum(1)					1-	1-		1-	1+					1+	
Trace Elements(12)		2+	1+	2+	2+	1+		1-	1+		1- ,2+	1+	2+	2+	2+
Particle Size(3)				1-											

[1] Positive value was at least 2 times the overall mean value

[2] Negative value was at least ½ time the overall mean value

were not expected. Only two macronutrients in Cluster I ($Mg(H_2O)$ and SO_4 (H_2O)) were at least one-half as low as the overall values for these variables. Cluster II had three variables higher than average (electrical conductivity and two trace elements (As and Cl)), and two low macronutrients (PO_4 -Ex and K-aval). Clusters III, IV, and V had the most deviations from the average values on Tract C-a, reflecting the small number of points clustered in each. For instance, Cluster III had nine high values and two low ones, while Cluster IV had eight high and seven low values. Cluster V deviations were limited to the general soil properties and macronutrients.

2. 84 Mesa

The distribution of data points among the five clusters was as unevenly distributed as it was for Tract C-a. Approximately 70 percent of the samples were in Cluster I and the number decreased sharply; Cluster II contained only about 5 percent of the sample.

Clusters V, IV and II had the lowest maximum (within cluster) distances, indicating that the soil characteristics of the vegetation types were very similar (Table 3.14). Since none of these three clusters contained more than four samples (all from sagebrush), these results would be expected. Yet, this clustering did emphasize the heterogeneity of soil traits in sagebrush, since these clusters were sufficiently dissimilar to be distinct from Cluster I.

Clusters I and III had relatively low maximum distances (1.5; 1.3 respectively) although they did have quite different sample sizes (27 versus 5). Therefore, the 27 sample points in Cluster I were almost as similar to each other as the five sagebrush points in Cluster III. Apparently Clusters I and II were most similar (minimum distance = 0.2) (Table 3.14), while Clusters II and IV were furthest apart (5.3). Clusters I and II were most dissimilar from Clusters IV and V, which were themselves relatively close (0.8). All these similarities and dissimilarities occurred in sagebrush, indicating that sagebrush is adaptable to a variety of soil characteristics.

Table 3.15 lists the relative proportions of each vegetation and soil type clustered together from 84 Mesa. The vegetation types which occur on 84 Mesa are limited to sagebrush and pinyon-juniper. Only Cluster I had both vegetation types.

The relatively low number of soil series (Rentsac, Yamac and Piceance series) which occur on 84 Mesa are similar to the few number of vegetation types. Cluster I contained all three types; Cluster II contained only the Rentsac and Piceance series; Clusters III and IV contained only Piceance; and Cluster V contained only Yamac. Although both Clusters III and IV contained the Piceance series, this type had sufficiently diverse soil traits to permit separate clustering.

Table 3.16 lists the mean values for each cluster and the overall means for 84 Mesa. The number of variables in each cluster that deviated from the overall mean for 84 Mesa is presented in Table 3.17. Clusters I and IV had the fewest aberrant values, but they had low values in general soil properties (electrical conductivity, adjusted conductivity, Na(H_2O)). Cluster IV had three high general properties and four high macronutrients. The other clusters each had approximately 10 high/low values, most of which were in the general soil properties and macronutrient categories. Thus, soils sampled in sagebrush on 84 Mesa include heterogeneous soil traits, particularly general soil properties and macronutrients. The micronutrients, gypsum, radioactivity, water-holding capacity, and particle size were more homogeneous on 84 Mesa.

3. Off-tract areas other than 84 Mesa

The sample points were distributed unevenly within the five clusters (I-129; II-4; III-6; IV-1 and V-1). This uneven distribution was similar to those for Tract C-a and 84 Mesa.

Cluster I (129 sample points) was grouped similarly to Clusters II or III (Table 3.14), although they differed in the total number of sample points. Clusters IV and V had maximum distances of zero because each contained only

one sample point. Cluster V, containing a single data point from riparian vegetation, was most widely separated from all the other clusters (Table 3.14) Cluster IV, which also contained a single riparian vegetation sample point, was the next most widely separated. Despite the fact that Clusters IV and V each represented a single riparian sample, these two were dissimilar in soil traits (minimum distance = 30.2). Clusters I, II and III were closer to each other than any of the other clusters, with three vegetation types (sagebrush, pinyon-juniper, and riparian) represented in all three clusters.

Table 3.15 lists the relative proportions of each vegetation and soil type clustered together for off-tract areas other than 84 Mesa. The off-tract diversity of vegetation types (8) and soil types (11) was higher than 84 Mesa (2, 3 respectively) or Tract C-a (5, 6 respectively).

Cluster I, which contained 92 percent of the data points, clustered sampling points from all eight vegetation types. Most sample points were represented by sagebrush (40 percent), pinyon-juniper (28 percent), and mixed brush (20 percent) in this cluster. The Soils collected from riparian habitat separated into all five clusters, and two riparian soil samples were sufficiently different to separate out from all the other groups in Clusters V and IV. For soil series, Clusters I, III and II had the most diverse grouping, while Clusters IV and V contained representative soil samples only from the Havre soil series. No single soil series dominated in Cluster I, but Irigul was in a marked minority, and was not represented in any other clusters. In fact, six out of the 11 soil series grouped in Cluster I were found only in that cluster.

All five clusters had aberrant values (Table 3.17) in general soil properties, macronutrients and trace elements from the mean overall soil values for the study area (Table 3.16). Cluster I, containing approximately 92 percent of the samples, had low values for one general soil property (Na-H_2O), three macronutrients (NO_3, Mg, Ca), and two high values for trace elements (Cl and Se). Cl was unusually high in all clusters.

4. Comparison of the cluster analyses for three locations

The number of sample points clustering in each location decreased from Cluster I to II: Tract C-a (120 to 4); 84 Mesa (27 to 2); and off-tract (129 to 4). The lowest maximum distance (1.5) occurred for 84 Mesa samples while Tract C-a (3.5 with 120 points) and off-tract (3.9 with 190 points) had comparable groupings for Cluster I.

Minimum distances were difficult to compare across locations, but the five clusters for 84 Mesa appeared closer together in their soil traits and each cluster appeared to be more similar than those for Tract C-a or off-tract.

Patterns of the relative proportions of vegetation types or soil series for each location were not apparent. Cluster I from each location always contained the most vegetation types and soil series but it was also consistently the largest cluster. The most frequent vegetation type in all five clusters was sagebrush and pinyon-juniper for Tract C-a, and sagebrush for 84 Mesa and off-tract areas. Shadscale and rabbitbrush were infrequently clustered for Tract C-a but the infrequent types (aspen, greasewood, Douglas-fir, balds, and riparian) did cluster for off-tract areas.

The most frequent soil series in the five clusters for Tract C-a were the Glendive and Torriorthent series. On 84 Mesa, the Piceance series was most common. The Havre series was found in all five clusters from off-tract areas.

Soil trait mean values of each cluster were compared to the overall mean for the general location. Since Cluster I contained most of the samples from any one location, it had the fewest deviations from the location average. For Tract C-a, two low macronutrients (Mg, SO_4) deviated from the overall mean. In comparison, 84 Mesa had three low general soil properties (electrical conductivity, adjusted conductivity, Na-H_2O) and three low macronutrients (Mg, Ca, SO_4). The off-tract areas had one low general soil property (Na-H_2O) and three low macronutrients (NO_3, Mg, Ca).

II. VEGETATION

Vegetation baseline data were analyzed to compare results from within major vegetation types and to determine the sample size needed to adequately sample each vegetation type (Sokal & Rohlf, 1969). Transect data from each type were compared by calculating community coefficient (CC) and percentage similarity (PS) values (Pielou 1974). Sagebrush, mixed brush, and pinyon-juniper are the major vegetation types on Tract C-a either because they occupy the greatest area or they provide important habitat for wildlife or both. The locations of the vegetation transects were presented in the RBOSP Terrestrial Annual Baseline Report (1976).

A. Community Coefficient and Percentage Similarity

Two measures were used to determine similarity between transects or homogeneity within vegetation types on Tract C-a. Community coefficient (CC) measures the similarity between species composition data whereas percentage similarity (PS) measures the similarity between species quantity data, in this case the herbaceous percent cover.

$$CC = \frac{200\,(S_{AB})}{S_A + S_B}$$

where: S_A = number of species in location A

S_B = number of species in location B

S_{AB} = number of species common to both A and B

If both locations have the same species, then $S_A = S_B = S_{AB}$ and CC will equal 100. If the transects have no species in common, then CC will equal zero.

$$PS = 200\,\Sigma_i \min\left(\frac{A_i}{Z}, \frac{B_i}{Z}\right)$$

where: Z = total quantity (percent cover) for both locations, A + B.

Z_i = percent cover of species in both locations A, B

A_i, B_i = percent cover of species in locations A, B therefore,

$Z = \Sigma^S Z_i = \Sigma^S_{i=1} \ (A_i + B_i)$

If all species are evenly divided between transects A and B, then $A_i = B_i = \frac{1}{2} Z_i$ for all species and PS equals 100 percent. If each species occurs only in A or B but not in both, PS equals zero.

If an area is spatially homogeneous, the species in any sample will be independent of its location in an area (Pielou 1974). However, if the vegetation type is spatially heterogeneous, the species composition will vary among samples. Pielou (1974) suggested that if the areas sampled are heterogeneous CC is a better similarity measure than PS. In contrast, if areas are similar in species composition, then PS is the preferred measure. Both measures were calculated for transects in major vegetation types on Tract C-a. Comparisons between Tract C-a and off-tract data provide information helpful in selecting control and impact sites for development monitoring. The CC and PS values reflect the degree of similarity between on-tract and off-tract sites before oil shale development could impact the area.

1. Sagebrush

Three comparisons of CC and PS were made among transects used to sample the sagebrush type (Table 3.18). Transects 4 and 5 were located on Tract C-a and transects 1, 2, 3 and 11 were located off-tract. The comparisons of transects 4, 5 vs. 1, 2, 3, 11 and 5 vs. 1, 2, 3 had the most similar CC and PS values. Comparison of transects 4 vs. 11 had the lowest CC (27) and PS (13) values while transect 5 vs 1, 2, 3 showed the most inconsistencies of the three comparisons. CC was relatively constant over seasons for 1975, but peaked in July for 1976. The PS values for 1976 were relatively constant.

The similarities for comparisons of transects 4, 5 vs 1, 2, 3, 11 and transects 5 vs 1, 2, 3 were not particularly high (approximate values: CC = 48; PS = 29) indicating that in each of these comparisons, the species composition was more similar that the quantities (percent cover) these species represented. The low similarity between transects 4 and 11 indicate that these locations are less acceptable as control or impact sites for monitoring than transects

TABLE 3.18

COMMUNITY COEFFICIENT (CC) AND PERCENTAGE SIMILARITY (PS) FOR TRANSECTS SAMPLED IN SAGEBRUSH, MIXED BRUSH, AND PINYON-JUNIPER DURING 1975 AND 1976 ON RBOSP TRACT C-a

Vegetation Type	Transect Comparison	Community Coefficient (CC)						Percentage Similarity (PS)					
		1975			1976			1975			1976		
		May	July	Sept.	May	July	Sept.	May	July	Sept.	May	July	Sept.
Sagebrush	4,5 vs. 2,3,11	42	51	52	53	49	38	33	38	28	32	29	26
	4 vs. 11	24	19	40	42	14	29	9	10	30	21	6	6
	5 vs. 1,2,3	41	44	45	48	53	38	28	38	23	28	28	24
Mixed Brush	1,2 vs. 3,7,9	40	40	42	44	49	54	19	15	14	14	12	12
	1 vs. 2	35	43	52	42	48	59	22	18	28	30	21	33
	3 vs. 9	24	22	48	17	21	25	10	8	13	4	7	7
Pinyon-Juniper	1,4,13 vs. 2,3,5,15	44	69	61	62	65	70	42	61	63	50	56	57
	1,13 vs. 2	36	67	57	42	61	64	22	32	41	31	40	35
	4 vs. 3	20	33	25	27	56	53	10	22	21	27	30	23

1, 2, 3, and 5.

2. Mixed Brush

Three comparisons of CC and PS were made among transects in mixed brush (Table 3.18). Transects 1 and 2 were located on or immediately adjacent to Tract C-a and transects 3, 7, and 9 were located west of tract. The PS values for all three comparisons were quite low, particularly for the comparison of 3 vs 9. Transects 1 and 2 had the most similar CC and PS values which will be considered when selecting monitoring sites in mixed brush habitat.

3. Pinyon-Juniper

Three comparisons of CC and PS were made among transects in pinyon-juniper (Table 3.18). Transects 1, 4 and 13 were located on tract and transects 2, 3, 5 and 15 were located in areas surrounding tract.

The comparison of transects 1, 4, 13, vs. 2, 3, 5, 15 had the highest CC and PS values. Species composition and percent cover of each species within the transects appeared to become more similar as the growing season progressed (Table 3.18). The values for transects 4 vs. 3 comparison were low and were the most inconsistent. The low similarity values for transects 4 vs. 3 indicate that these transects should not be considered as potential monitoring sites.

4. Comparison between types

The degree of similarity in species composition (CC) for all three vegetation types was highest in pinyon-juniper (Table 3.18). The CC values for mixed brush and sagebrush transects were similar. The PS values were also greatest for pinyon-juniper, indicating the greatest degree of similarity in species composition and percent cover. Mixed brush had the lowest PS values for both years. The CC or PS values rarely exceeded 50 percent for any of the three vegetation types. The low similarity between transects within vegetation types indicates a great degree of spatial heterogeneity within each habitat type. In general transects on-tract were similar as a group to off-tract transects.

B. Adequacy of Sample Size

Adequate sample size depends on the amount of variation in the sample and the precision required by the program design. Adequacy of sample size was determined for each habitat type for three seasons in 1975 and 1976. For these calculations, an aribitrary precision of ±10 percent of the mean 90 times out of 100 was selected. Sample sizes required for each habitat type were estimated using herbaceous percent data collected during the baseline period. Adequate sample size was calculated (Sokal & Rolhf, 1969):

$$n_{min} \geqq \frac{2s^2 \cdot Z^2}{(a \cdot \bar{x})^2}$$

where:	n_{min}	=	minimun number of samples required
	s	=	standard deviation
	Z	=	one tailed t-value with infinite degrees of freedom
	a	=	precision desired (.10 percent)
	$\bar{x}$	=	mean value

1. Sagebrush

Adequate sample size was determined using data for each transect and for all six transects combined (Table 3.19). The minimum sample size required for sagebrush (based on all six transects) ranged from 268 to 564 with an average of 403.

The range within individual transects was great (22 to 999). Transects 4 and 11 accounted for the greatest variability; these transects also had low CC and PS values (Table 3.18). Sample sizes for the other four transects ranged from 22 to 250, substantially less than those for transects 4 and 11. The low CC and PS values and high sample size for transects 4 and 11 indicated a degree of heterogeneity which is substantially greater than for the other four sagebrush transects.

TABLE 3.19

ADEQUATE SAMPLE SIZE[1] FOR MIXED BRUSH, SAGEBRUSH AND PINYON-JUNIPER ON RBOSP TRACT C-a FOR EACH SAMPLING PERIOD DURING 1975 AND 1976.

Vegetation Type	Transect	Sampling Period					
		1975			1976		
		May	July	Sept.	May	July	Sept.
Sagebrush	1	59	61	115	76	118	178
	2	164	37	44	22	34	250
	3	162	57	64	70	73	73
	4	659	217	117	379	275	364
	5	93	56[2]	45	58	89	105
	11	919	999	340	800	773	444
	All 6 Transects	401	298	411	268	473	564
Mixed Brush	1	113	87	140	119	115	289
	2	291	148	213	253	845	192
	3	40	145	48	240	146	186
	7	294	187	272	146	113	135
	9	167	168	150	337	226	141
	All 5 Transects	293	180	288	287	460	299
Pinyon-Juniper	1	479	260	205	449	348	303
	2	75[2]	40	75	73	70	104
	3	999	163	133	255	311	261
	4	365	332	228	210	280	452
	5	538	502	387	371	467	715
	13	241	190	185	161	178	175
	15	271	338	491	580	344	441
	All 7 Transects	452	307	272	431	328	502

[1] ± 10% of mean 90 times out of 100

[2] Program does not calculate adequate sample size greater than 999.

2. Mixed Brush

Adequate sample size was determined for each transect and for all five transects combined (Table 3.19). As with sagebrush, the number of replicate plots required to adequately estimate percent cover in the mixed brush habitats was high. The sample size required ranged from 180 to 460 with an average of 301. Sample size calculated for individual transects ranged from 40 to 337, except for transect 2 in July 1976. Transects 3 and 9 had low CC and PS values (Table 3.18) but sample sizes required for these transects were not substantially greater than those for other transects. This may indicate that the species composition sampled by these transects was similar within each transect but different from the other mixed brush transects sampled.

The adequate sample size results reflected the great heterogeneity in the herbaceous stratum in the mixed brush habitat.

3. Pinyon Juniper

Adequate sample size was estimated from data for each transect and for all seven transects combined (Table 3.19). For all seven transects, the minimum number of samples required for adequate sampling ranged from 272 to 502, with an average of 382. Transect 2 consistently required the fewest number of samples.

4. Comparison between types

The sample size required to attain a precision of 90 percent was so large that a sampling program of this magnitude is not practical for Tract C-a because of the heterogeneity in the major vegetation types and prohibitive time and cost constraints. Therefore, adequate sampling size estimates based on a precision of 75 percent were calculated for combined transects for each habitat type. These estimates are presented below.

	1975			1976		
	May	July	September	May	July	September
Sagebrush	65	48	66	43	76	85
Mixed Brush	47	29	46	46	74	50
Pinyon-Juniper	72	49	44	69	52	80

The minimum number of samples required ranged from 29 to 85, a sampling intensity that seems both practical and feasible. The future RBOSP monitoring program will be designed to achieve a minimum precision level of 75 percent.

III. Interrelationships Among Vegetation and Abiotic Factors

A Spearman rank correlation (Elliot 1971; Snedecor 1956) was used to make paired comparisons between vegetation and soil properties, between vegetation and cumulative precipitation, and between various soil traits.

Spearman's rank correlation coefficient (r_s) is calculated as:

$$r_s = 1 - \frac{6\Sigma d^2}{n(n^2 - 1)}$$

where: n = number of pairs of observations
d = difference between each pair of ranked values

The Spearman rank correlation coefficients are presented in Table 3.20 Only three of the 20 comparisons were significant at the 95 percent level. The significant correlation between soil depth and percent cover indicates the importance of soil depth to the distribution of vegetation types on Tract C-a. The specific relationships between each habitat type and soil depth are discussed in Chapter 1 of this section.

Percent cover for the combined vegetation types was significantly correlated with cumulative precipitation, but shadscale was the only separate type that showed a significant correlation (Table 3.20). Apparently, other factors,

TABLE 3.20

SPEARMAN'S RANK CORRELATION COEFFICIENTS FOR PAIRED OBSERVATIONS AMONG PERCENT COVER FOR SIX MAJOR VEGETATION TYPES[1], SOIL CHARACTERISTICS, AND CUMULATIVE PRECIPITATION FOR RBOSP TRACT C-a.

	Comparisons	Spearman's Rank Correlation Coefficient (r_s)
Vegetation and Soil Interrelationships	Percent Cover vs. Soil Depth within 6 vegetation types	0.986[1]
	Percent Cover vs. pH within 6 vegetation types	0.720
	Percent Cover vs. PO_4 within 6 vegetation types	0.714
	Percent Cover vs. NO_3 within 6 vegetation types	-0.314
	Percent Cover vs. Organic Matter within 6 vegetation types	0.200
	Percent Cover vs. Conductivity within 6 vegetation types	-0.200
	Percent Cover vs. Water-Holding Capacity within 6 vegetation types	0.049
Vegetation and Meteo-rological Interrelation-ships	Percent Cover of Shadscale vs. Cumulative Precipitation	0.962[2]
	Percent Cover of 6 vegetation types vs. Cumulative Precipitation	0.84
	Percent Cover of Pinyon-juniper vs. Cumulative Precipitation	0.429
	Percent Cover of Rabbitbrush vs. Cumulative Precipitation	0.429
	Percent Cover of Sagebrush vs. Cumulative Precipitation	0.371
	Percent Cover of Mixed Brush vs. Cumulative Precipitation	0.257
	Percent Cover of Greasewood vs. Cumulative Precipitation	0.143
Soil Interrelationships	Organic Matter vs. Water-Holding Capacity within 6 vegetation types	0.828
	Conductivity vs. Organic Matter within 6 vegetation types	-0.600
	Conductivity vs. Water-Holding Capacity within 6 vegetation types	-0.200
	Soil Depth vs. Water-Holding Capacity within 6 vegetation types	-0.200
	NO_3 vs. PO_4 within 6 vegetation types	-0.085
	Soil Depth vs. Organic Matter within 6 vegetation types	-0.014

[1] Six vegetation types include sagebrush, pinyon-juniper, mixed brush, shadscale, greasewood, and rabbitbrush.

[2] Significant at the P = .05 level.

were also important in determining seasonal herbaceous cover for the other five habitat types.

None of the rank correlations between soil traits were significant (Table 3.20). Only organic matter and water-holding capacity were close to being significantly correlated. The correlation matrix performed for the soil cluster analyses (discussed earlier) showed a correlation coefficient of 0.62 for organic matter and water-holding capacity (at 15 bars).

IV. Conclusions

The analyses performed on the Tract C-a baseline data indicated a high degree of heterogeneity within the vegetation types. This heterogeneity dictates that large sample sizes are required to adequately sample vegetation or that lower levels of sampling precision must be accepted. This heterogeneity was reflected in the low similarity values of species composition (CC) and quantity (PS) of vegetation between sampling locations. Future vegetation monitoring sites will be selected from the most similar sampling locations.

Heterogeneity was also indicated in the soils data. Principal component analysis indicated that one or two soil traits cannot be isolated as indicator or control factors. The general soil properties and macronutrients accounted for much of the variation indicated in the soils studied.

The cluster analysis of soil characteristics for three locations indicated that approximately 85 percent of the sample sites were in one of the five resulting clusters. The remaining samples apparently represented soil characteristics whose values deviated from average levels. Care will be taken to avoid soil sampling sites included in the other four clusters when selecting soil monitoring sites.

The results of the analysis of the Tract C-a habitats indicate the complexity of the ecological system and the difficulty in identifying one or two

parameters which can be used as indicators of the system. The inherent complexity makes accurate sampling difficult but should insure stability and resiliency as perturbations occur.

CHAPTER 4 - RANGE AND BROWSE

ABSTRACT

Five different range analysis studies (range, browse, and soil condition and trend, range production-utilization, browse condition and utilization, grazing exclosure, and domestic livestock census and distribution) were conducted on the Tract C-a study area to obtain some understanding of the capacity of the study area's rangelands to support large herbivores.

Range, browse, and soil conditions and trend studies revealed that 97 percent of the study area's rangeland was in fair (73 percent) to poor (24 percent) condition. Pinyon-juniper and sagebrush vegetation types accounted for most of the area rated as fair to poor. Forty-eight percent of the surveyed area showed an improving trend in range condition, mostly in the mixed brush and sagebrush vegetation types, while a downward trend in range conditions was recorded for most of the remaining area surveyed, the majority of which was in the pinyon-juniper vegetation type.

Soil condition and trend, largely attributed to the amount of ground cover, were predictably poor throughout the pinyon-juniper vegetation type where ground cover is sparse; however, the generally poor soil condition noted for other vegetation types are not as easily explained.

Sagebrush and mixed brush vegetation types demonstrated the highest forage production while the greatest forage utilization was noted for mixed brush and bald vegetation types. Forage utilization across the study area showed a strong elevational zonation corresponding roughly to the summer distribution of large herbivores on the study area.

Browse condition and utilization studies revealed that seven different browse species comprised 98 percent of the shrubs sampled in two principal vegetation types (mixed brush and pinyon-juniper). Of these, bitterbrush and mountain mahogany received the heaviest utilization in the

higher elevation mixed brush type while bitterbrush and serviceberry received the heaviest utilization at lower elevation pinyon-juniper sites.

Whereas phytosociological studies and their results (Chapter 2) may be most useful in obtaining an understanding of the existing ecological conditions of Tract C-a vegetation, knowledge of the capacity of that same vegetation for supporting animal life, and current trends in that capacity, is best obtained through an entirely different set of studies, collectively addressed under the term Range and Browse. Such studies are conducted from the perspective of land managers for the purpose of obtaining a practical basis for land use decisions. The general objective of Range Analysis studies performed in the Tract C-a vicinity was to provide an updated information base for land management decisions, particularly as a basis for sound recommmendations on habitat manipulations to mitigate the effects of oil shale development. Specific objectives are identified in the following discussion of the Range Analysis program. Program elements to be discussed include (1) range, browse and soil conditions and trend; (2) range production and utilization; (3) browse utilization; (4) the grazing exclosure program; and (5) domestic livestock.

I. RANGE, BROWSE AND SOIL CONDITION AND TREND

Range, browse and soil condition and trend are the principal criteria influencing management decisions for large herbivores (cattle, deer, horses) on government-administered lands. The element of the Range Analysis program provided data on the current condition of range and browse species in relation to the potential of which each site investigated is capable. Trend, the inclination toward improvement, stabilization, or deterioration, was also determined. Methods used in condition and trend studies presented here are relatable to those employed by state and federal agencies having jurisdiction in the area. Thus, data presented here should facilitate land management decisions by those state and federal agencies. The survey area was located in a region which would encompass Tract C-a and the full spectrum of elevational zones and vegetation types which surround it. See Figure 3-7-20

in the RBOSP Terrestrial Annual Report (1976) for range analysis sample site locations on the study area..

Range condition classifications are predicated upon the hypothesis that local vegetation is the product of a local environment, subject to physical, edaphic, and biotic influences and limitations. The vegetation of many western rangelands has never attained its theoretical climax status because of one or more of these limitations. Many of these rangelands have been heavily grazed or browsed for long periods of time. As a result the carrying capacity of the range is often much less than the potential of which a particular area is capable. However, the time required to recover or to achieve climax condition may preclude that condition from being a practical management objective (Stoddart and Smith 1955). In other rangelands the influence of localized limiting factors may dictate that few sites in a given area have even the potential for achieving climax status.

The fact that range condition for nearly all of the 35,269 acres representative of study area vegetation types in the vicinity of Tract C-a was classified as fair (73 percent) to poor (24 percent) may be explained by either use history or site limitations (or some combination of the two). A general lack of historical data makes it difficult to determine the relative importance of use history as opposed to site limitations for any given location. None of the surveyed range was classified as being in "Excellent" condition and only about two percent was classified in "Good" condition. Most of this acreage was in sagebrush communities. Pinyon-juniper and sagebrush vegetation types accounted for most of the area rated in the "Fair" to "Poor" condition class.

The trend in range condition was rated as improving on about 48 percent of the surveyed area, mostly in the sagebrush and mixed brush vegetation types. A downward trend was recorded on most of the remaining area, largely occupied by the pinyon-juniper vegetation type. Sites totaling 8.2 percent of the area exhibited stability or no apparent trend.

Soil condition and trend ratings are largely attributed to the amount of ground cover including vegetation, rocks, and litter relative to the amount of bare

erodable ground. The pinyon-juniper vegetation type commonly exhibits very low ground cover. Therefore, the high percentage of soil rated as being in poor condition (99 percent) was not unexpected. However, the high percentage of sagebrush, mixed brush, and upland meadow classified as having poor to very poor soil condition (78, 96 and 100 percent respectively) are not as easily attributed to natural conditions. Only about eight percent of the sampled area was rated as having fair to good soil condition, 80 percent of it occurring in the sagebrush vegetation type. Only 0.4 percent of the study area sampled was rated as having an "Excellent" soil condition, all of it in the aspen type. With regard to trends in soil condition, 62 percent of the study area was classified as showing a deteriorating condition, primarily in the sagebrush, pinyon-juniper, and bald types. Soils in the mixed brush type appeared to be stable whereas all soils in the aspen type showed an upward trend.

Browse condition studies considered three possible condition classes - good, fair, and poor. Browse condition was determined to be almost entirely within the "Good" condition class (98.4 percent). A collective area of sites, totalling 1.4 percent of the study area, was place in the "Fair" condition class. Only 0.2 percent of the study area, all in the Douglas-fir type, was judged to be in "Poor" browse condition.

Even though most of the browse was in good condition, the largest portion (60 percent) exhibited a deteriorating or downward trend. Thirty percent of the area showed no apparent trend. Only 10.3 percent of the area was rated as being in an upward or improving trend.

II. RANGE PRODUCTION - UTILIZATION

Grass and forb production studies were undertaken to measure the rate of forage production per unit area in each major vegetation type during a representative portion of the growing season. Measurements were also made of forage utilization by large herbivores at the end of the production period.

The data suggest low production value in the vicinity of Tract C-a (Table 3.21). Although these low productivity figures in concert with poor range conditions and a downward trend could be indicative of prolonged heavy grazing, resulting in reduced plant growth, the production figures should be viewed with caution in this regard.

Productivity is also highly correlated with meltwater available from winter snowpacks and spring rains such that higher productivity is commonly expected with increasing elevation. This would lead to the expectation that forage production would be highest in the grass bald and mixed brush types at higher elevations and lowest in the sagebrush type at lower elevations. Actual results obtained at Tract C-a are more complicated than this. While sagebrush did show the highest productivity of any vegetation type sampled, productivity in the bald type was much lower. It is likely that bald sites are frequently swept clean of snow accumulations by winter winds and so do not receive the benefit of precipitation ocurring as snow. In addition, aerial surveys revealed that balds are utilized heavily in the winter by feral horses, contributing even more to lower productivity. Pinyon-juniper sites, on the other hand, showed the lowest rates of production due largely to low densities of grasses and forbs. This may result from a variety of conditions including shallow, coarse-textured soils with a low moisture holding capacity, shading by the tree canopy, antibiosis effects of litter accumulating in the understory, as well as possible lower rates of precipitation at generally lower altitudes (Ward, Slauson and Dix 1974).

Large herbivore utilization of grasses and forbs, as revealed by comparisons between protected and unprotected plots, was heavily related to the elevational zonation of vegetation types as well as to the availability of forage in the different vegetation types. Heaviest use occurred on the bald sites (the bald areas atop the highest ridges in the study area). The next heaviest use was found in the mixed brush vegetation type, which occurs primarily in the

TABLE 3.21

FORAGE PRODUCTION AND UTILIZATION ESTIMATES 1/

OBTAINED IN THE FALL 1975 ON AND NEAR TRACT C-a

Tract C-a Vegetation Type	Dry Weight Production lbs/A (Kg/ha)	No. of Samples	Standard Error lbs/A (Kg/ha)	Drilled Forage lbs/A (Kg/ha)	Percent Utilization 2/
Pinyon-Juniper	100.5 (113.6)	210	6.85 (7.74)	46.8 (52.9)	31.8
Sagebrush	268.7 (303.6)	200	30.65 (34.63)	21.8 (24.6)	7.5
Mixed Brush	206.6 (233.5)	130	11.19 (12.64)	128.0 (144.6)	38.2
Bald	135.2 (152.8)	100	12.09 (13.60	91.8 (103.7)	40.4

1/ Table values have been adjusted to correct for minor errors in results reported in Second Annual Report (RBOSP, 1976)

2/ Percent utilization = $\dfrac{\bar{X}\text{ cage plot field wt} - \bar{X}\text{ occular plot field wt.}}{\bar{X}\text{ cage plot field wt.}} \times 100$

next lower elevational zone. Intermediate use was seen in the pinyon-juniper vegetation type. Lowest utilization was found on the sagebrush vegetation type at the lowest elevations sampled. These observations correspond to the observed distribution of large herbivores during most of the summer.

III. BROWSE CONDITION AND UTILIZATION

Tract C-a is believed to be located on the periphery of the prime wintering grounds for mule deer in the Piceance Basin. The objective of browse studies conducted in the study area was to define the condition of browse species and their present degree of utilization, prior to Tract C-a development. With this information as a basis, the effects of tract development on browse utilization patterns and the efficacy of management plans to offset any negative effects can be evaluated.

Three kinds of information are of great utility in interpreting the present condition of browse species (shrubs and trees) in relation to their current use by large herbivores in the Trace C-a vicinity. These are (1) the present degree of utilization of current annual growth (CAG) as it affects browse availability, (2) the percentage distribution of sampled shrubs into form classes ranging from shrubs on which all CAG is available (reachable) to large herbivores (form class 1) through a series of increasingly heavily hedged and/or unavailable (out of reach) forms, and (3) the percentage distribution of shrubs into age classes.

At each of 100 sampling locations distributed throughout two of the principal vegetation types (mixed brush and pinyon-juniper), twenty-five individual shrubs were evaluated. The data obtained are summarized for the seven browse species which represented more than 98 percent of the shrubs sampled (Table 3.22).

Within a given vegetation type it is useful to compare results between the predominant species. In the mixed brush type, generally occurring at higher altitudes or on more northerly facing slopes, serviceberry and sagebrush were the browse species most commonly encountered, combined with an admixture of

TABLE 3.22

CONDITION OF SEVEN PRINCIPAL BROWSE SPECIES SAMPLED IN TWO PREDOMINANT VEGETATION TYPES DURING APRIL, 1976, FOR RBOSP.

Species	Veg. Type 1/	No Plants Sampled	Average % Util.	Average % Avail.	Form Class Percentages							Age Class			
					1	2	3	4	5	6	7	Seedling	Young	Mature	Decadent
Serviceberry	MB	643	11.1	98.4	76	11	2	11	1				1	95	4
	PJ	202	69.1	99.8	19	31	48	1		0.4			6	88	6
Sagebrush	MB	352	4.9	100	100							0.2	4	93	2
	PJ	328	7.2	100	93	7						0.3	12	69	18
Pinyon Pine	MB	17	6.8	94	88			11					23	76	
	PJ	259	12.4	67.8	42	6	1	37	8	3		4	20	72	2
Rabbitbrush	MB	22	9.3	100	95	5								100	
	PJ	94	6.2	100	97	3							8	83	8
Bitterbrush	MB	45	46.9	100	22	44	24	9						100	
	PJ	153	73.8	100	3	40	56						0.6	93	6
Mountain Mahogany	MB	58	47.1	99.4	38	34	21	3	3				7	90	2
	PJ	62	52.4	93.3	13	48	31	5	3					98	2
Juniper	MB	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	PJ	225	6.0	49.6	29	0.9		65	2		2	1	12	77	10

1/ MB = Mixed Brush
PJ = Pinyon-juniper

bitterbrush and mountain mahogany. Of these, the fewer bitterbrush and mountain mahogany shrubs tended to show moderate to heavy hedging whereas sagebrush was only lightly hedged. Most shrubs sampled were mature although mountain mahogany and sagebrush revealed a moderate number of young plants. Shrubs occurring in the pinyon-juniper type (generally at lower altitudes or on more southerly facing slopes than the mixed brush type) may be listed in their relative order of abundance as, sagebrush, serviceberry, bitterbrush, rabbitbrush, pinyon, and juniper. Of these, serviceberry and bitterbrush showed percentages of utilization in excess of those recommended as optimum management goals (60 and 50-65 percent respectively) for southwestern Colorado (Shepherd 1971) big game ranges. This use level is also reflected in the high percentages of these two species which showed evidence of moderate to heavy hedging. Rabbitbrush and sagebrush, on the other hand, showed very low levels of utilization and light hedging. Although most shrubs sampled were classed mature, a fair number of both young and decandent rabbitbrush, serviceberry and (particularly) sagebrush individuals were represented. There were 10 times more decadent than young bitterbrush shrubs.

The most interesting comparisons to be made between the two vegetation types sampled are those for each shrub species. For nearly all browse species, the percentage of utilization was higher in the pinyon-juniper type than in the mixed brush type. This was particularly true for bitterbrush (74 percent in pinyon-juniper versus 47 percent in mixed brush) and serviceberry (69 percent pinyon-juniper versus 11 percent in mountain brush). Again, higher percentages of utilization are related to more shrubs in the moderate to heavily browsed form classes. In browse species held in common by the two vegetation types (except mountain mahogany) there appears to be a greater concentration of individuals in in the mature age class for mountain brush than for pinyon-juniper.

The overall patterns of browse condition described above may be accounted for at least part, by (1) the recent history of the study area and (2) observed patterns of distribution of large herbivores, particularly mule deer, in the study area. The 1972-73 winter was extremely severe, resulting in as much as a 40 percent reduction in the Piceance basin deer herd. Following winters have been relatively mild, particularly during the winter of 1975-76. Thus, not only

has the number of mule deer utilizing study area browse been drastically reduced, the effect of the fewer remaining deer has been more widely dispersed. As a result, combining the degree of hedging (browse condition) with the proportion of young to decadent plants (browse trend) yields a rating of good to excellent on 88 of the 100 transects sampled. The additional observation that only 78 percent of the transects sampled in pinyon-juniper were rated as good to excellent, whereas 100 percent of the transects in mixed brush were so rated may be explained on the basis of mule deer distribution patterns. In the Tract C-a vicinity, most of the mixed brush vegetation is to the west of the primary deer winter range. Snow accumulations generally force mule deer to more eastern areas early in the winter and permit deer to return only late in the spring. Thus, while the mixed brush type may appear to be the better deer habitat in the area, circumstances force the deer to utilize shrubs in the pinyon-juniper type more heavily. Thus, for example, the relatively heavy use of serviceberry in the pinyon-juniper type occurs because this type is located in the western margin of Piceance basin winter range. In the summer, so wide an expanse of mountain brush type becomes available still further to the west that the relatively few summering animals simply cannot begin to exploit it. Hence, we observe only 11 percent utilization of serviceberry

The fact that this same trend is not as pronounced for browse species like mountain mahogany and bitterbrush may be accounted for by increased selectivity on the part of summering mule deer. It has been observed in the study area that in an area where certain browse species are available in great abundance (serviceberry in this case) deer may seek out the less common species (mountain mahogany and bitterbrush).

IV. GRAZING EXCLOSURE

The grazing exclosure established on lower Airplane Ridge near the southwest corner of Tract C-a was designed to demonstrate and monitor vegetation responses to protection from the influence of particular groups of grazing or browsing herbivores. Various forage species can be expected to respond to protection according to their position in the hierarchy of consumer preferences. Thus, the most desirable components of the plant community should

react most dramatically to a release from the restraints exercised upon them by certain herbivores. In addition, the long-term collection of data from the grazing exclosure can yield information about the relative importance of the different vertebrate herbivore groups as consumers in the vicinity of Tract C-a. The data discussed in this section are baseline material intended for comparison with data from future years. It is important to recognize that initial differences between sample grids may exercise considerable influences on the responses elicited from the various treatments. Current differences can be attributed to slight variations in slope and aspect within and between the sample plots. It should be understood that these influences will exert differential pressures on the responses of each sample site and that these responses will not necessarily be directly proportionate to the degree of protection from grazing and browsing. The response of sample sites to degrees of release from grazing pressures will be measured in future years with aforementioned considerations in mind. Data were collected from three strata (grass-forb, shrub, and tree) in the grazing exclosure compartments during late summer 1975 and 1976. The data from the two years were summarized and analyzed comparatively as a check for the early appearance of any marked trends.

Results from grass-forb stratum sampling (Table 3.23) were analyzed to determine if any significant changes in forage production had appeared in the first two years as a result of differential release from grazing pressure. Although a reduction was noted in production (dry matter) per unit area between 1975 and 1976, this was probably due to local conditions being less favorable to plant growth in 1976 than in 1975. No statistically significant differences in production were noted between compartments over the two years. This fulfills the expectation that longer term investigations are needed to yield the desired information about the relative roles of the different vertebrate herbivore groups in forage production and utilization in the study area.

Due to overriding variations in sampling methodology, the dry-weight production estimates from this grazing exclosure clipplot program are not directly comparable with similar estimates from other sources (United States Department of Agriculture, Soil Conservation Service 1975; C-b Shale Oil Project 1976;

TABLE 3.23

GRAZING EXCLOSURE CLIPPLOT RESULTS
FOR 1975 AND 1976 RBOSP

Compartment	N	Dry Wt. Production[1/] 1975	1976	Standard Error 1975	1976
A	50	107	86	2.40	1.59
B	100	532	347	5.05	4.00
C	150	370	227	4.08	2.35
D	150	304	152	2.56	1.39

1/ Expressed as Kg/ha.

VTN Colorado Inc. 1976).

Shrub plot and tree intercepts sampling results (Table 3.9 and 3.10 in RBOSP Progress Report 10, 1977) showed no significant differences between grazing exclosure compartments. Two years of shrub photoplot records were analyzed by a t-test for paired comparisons. The results of this analysis suggest no significant change has occurred in the sizes of the sampled shrubs during the course of the study. This suggests that the investigation might be of longer duration to adequately detect and measure trends of change in these shrub species and to deduce therefrom the relative impact of the various vertebrate herbivores on big sagebrush and bitterbrush browse.

V. USE BY DOMESTIC LIVESTOCK

Numbers of livestock and areas they use were determined on a seasonal basis to help define the extent and type of grazing pressure exerted by domestic herbivores in the study area.

Cattle (*Bos taurus*) and domestic horses (*Equus caballus*) are the livestock occurring on the RBOSP study area. The very limited number of domestic horses in the study area were generally confined to corrals near ranches unless they were being used to herd cattle. The cattle which ranged throughout the study area, accounted for the most domestic livestock use.

Three Bureau of Land Management (BLM) grazing allotments exist in the vicinity of Tract C-a. Maps showing the areal extent of these allotments are included in the RBOSP Terrestrial Annual Report (1976). The Reagle and Square S Allotments have been placed under allotment management plans (AMP). The BLM is presently preparing an AMP for the Box Elder Allotment. The AMP's allow the BLM broader flexibility in establishing stocking rates depending upon year to year range conditions. The allotments are described as follows:

- Square S Allotment - 25,940 ha (64,050 acres) of BLM lands, 4,734 ha (11,689 acres) of private lands for total of 30,674 ha (75,739 acres). The grazing season is from May 5 through November 25. The BLM has estimated

a carrying capacity of 5,896 Animal Unit Months (AUM) based on a 1941 Range Survey. The recent chaining of 1,822 ha (4,500 acres) of pinyon-juniper was estimated to add 787 AUM's to that capacity. An Allotment Management Plan was formulated and implemented in 1969, and was updated in 1972. Actual (licensed) stocking rates in the last five years were as follows.

1971	not available
1972	4,535 AUM's
1973	3,759 AUM's
1974	3,290 AUM's
1975	4,871 AUM's

- Box Elder Allotment - 10,559 ha (26,071 acres) of BLM land, 895 ha (2,210 acres) of Colorado Division of Wildlife (CDOW) lands, and 797 ha (1,970 acres) of private lands result in a total allotment of 12,251 ha (30,251 acres). The grazing season is from June 23 through October 8. The BLM has estimated a carrying capacity of 1,517 AUM's, based on a 1973 Range Survey. Actual (licensed) stocking rates for the period 1971-1975 were:

1971	1,344 AUM's
1972	1,344 AUM's
1973	1,344 AUM's
1974	1,124 AUM's
1975	1,124 AUM's

- Reagle Allotment - 9,620 ha (23,753 acres) of BLM lands and 887 ha (2,190 acres) of private lands for a total of 10,507 ha (25,943 acres). The grazing season extends from May 3 to September 15. The BLM has estimated a carrying capacity of 2,318 AUM's based on a 1941 Range Survey. Actual (licensed) use in the past five years has been:

1971	1,266 AUM's
1972	2,097 AUM's
1973	1,473 AUM's

1974	1,773 AUM's
1975	1,334 AUM's

Recent range improvements include a fencing project in 1971 and water developments in 1973 for enhancing management systems. An Allotment Management Plan was initiated in 1969, and implemented on the Reagle Allotment in 1971.

The northwest half of Tract C-a is in the Box Elder Allotment and the remaining portion is in the Square S Allotment. Since cattle range freely on and off the Tract within the allotments, actual stocking rates in AUM's have not been calculated for Tract C-a. The BLM estimates the carrying capacity of Tract C-a to be 600 AUM's (personal communication K. Russell, BLM, Meeker CO., November 1976). Cattle distribution and dispersal in the Tract C-a area are initially dictated by herding, but elevational and seasonal changes on the range are also important considerations (refer to Figure 3.10 in RBOSP Progress Report 10, 1977, for cattle distributions observed during the study). During the period from January through April, cattle were located in the lower elevations of the study area. They were generally observed in the bottomland meadows in Ryan Gulch, Black Sulfur Creek, Yellow Creek, and Duck Creek and concentrated when and where they were provided supplemental feed. Grazing seasons commence in early May over most of the study area and animals start to disperse from the winter feeding areas. Cattle on 84 Mesa during June were generally scattered east of the road on the lower elevations of the Box Elder allotment. Cattle were also distributed between Wolf Ridge and Ryan Gulch and a few were on Cathedral Bluffs west of Tract C-a. By August, cattle were widely scattered throughout the western portion of the study area and very few remained east of Tract C-a. Cattle grazed on the higher elevations throughout the summer. The animals started to move to lower elevations during October and by November were distributed on Tract C-a, 84 Mesa, and Wagon Road Ridge. During late November and December, most cattle were wintering in the bottomland meadows of Duck Creek, Yellow Creek, Ryan Gulch, and Black Sulfur Creek. The animals were more widely scattered during December than in January and February.

Cattle concentrated and loafed near water sources and scattered to graze

within easy travel distance of these areas during the summer. In several instances, salt stations were located at water holes, which contributed to cattle concentrations there. For example, salt stations were observed at the end of the road in Corral Gulch when the creek was running, and just off the road north of the pond in Stake Springs Gulch. Other salt stations were observed at convenient drop locations on Cathedral Bluffs. Forage was quickly depleted where salt was located near water and the cattle were forced to range farther from the source of water and/or salt as the grazing season progressed. Where water is limited, its distribution may cause range utilization problems due to complete forage utilization near the water sources (Stoddart et al. 1975).

Toward the middle of summer, water availability became a more critical factor limiting livestock distribution. Water sources on Corral and Ryan Gulches dried up by mid-summer, leaving Water and Spruce Gulches, Stake Springs, Cottonwood Spring, Maverick Spring and Duck Creek as the only sources.

As mentioned in preceeding sections, range condition and trend classes are affected in part by the grazing impacts exerted by domestic livestock. There are, however, many abiotic and biotic interactions which influence range condition and trend, making a detailed cause/effect analysis of only one factor difficult. When addressing the range condition, trend and grazing interactions, the group of grazers must be considered. The combined impact of herbivorous mammals such as domestic livestock, wild horses, big game, and smaller herbivores is the most amenable to manipulation by man. Man has his greatest control over the domestic livestock use of an area by placement of water holes, fences, and salt stations. Although the domestic livestock rates have been below the estimated carrying capacity of the range, the concentration of domestic livestock combined with the wild ungulates using the Box Elder Allotment could cause overgrazing on this portion of the study area. The range condition and trend studies indicated a state of relative equilibrium for vegetation and a downward trend for soil on this allotment. The BLM is currently preparing an Allotment Management Plan for the Box Elder Allotment which will help to alleviate this problem by taking into account pressures exerted on the range by ungulates other than domestic livestock.

Relative preferences of herbivores for various plant associations may be indi-

cated by utilization studies. Bald and mixed brush vegetation types received the highest utilization while pinyon-juniper and sagebrush received lower utilization. Cattle were frequently observed grazing on the bald and mixed brush types west of Tract C-a during the summer. Hubbard and Hansen (1976) report that the principal foods of cattle in the vicinity of the RBOSP study area were sedges (*Carex* spp), needle and thread (*Stipa comata*), wheatgrass (*Agropyron* spp), prairie junegrass (*Koeleria cristata*), bromes (*Bromus* spp), Indian ricegrass (*Oryzopsis hymenoides*), bluegrasses (*Poa* spp), and common winter fat (*Eurotia lanata*). Cattle received supplemental feed during a portion of the time they were in the lower pinyon-juniper and sagebrush types so they did not have to rely totally on forage produced in these types. The greatest proportion of deteriorating rangelands were in the pinyon-juniper vegetation type and this may be due in part to the combined factors of feral horses using the type the entire year, mule deer and feral horses concentrating in the type to seek shelter from storms in the winter, and the cattle using the type in spring and fall when they were not provided supplemental feed, as well as abiotic limiting factors.

CHAPTER 5 - WILDLIFE

ABSTRACT

The presence of 30 different small (and medium-sized) mammals was detected by live, removal, and pitfall trapping techniques, night spotlight censuses, mist netting (for bats), and opportunistic observations in the vicinity of Tract C-a. Data obtained from over 6,300 individuals comprising 14 different species during live trapping operations provided important information relevant to the determination of the distribution, movements, abundance, and definition of important population parameters for small mammal species, the designation of important species, and the identification of important small mammal habitats.

Small mammal species ultimately depend upon the vegetation for their cover, source of food, and, frequently, their only supply of water. Consequently, the amount and type of vegetation in a particular habitat were found to be important factors regulating the distribution and abundance of small mammals. In habitats below 8,000 feet, small mammal abundance was closely related to percentage of shrub cover. Habitats above 8,000 feet showed the same relationship between shrub cover and abundances, although total abundance was generally lower than in low elevation habitats.

Mule deer were the most abundant large mammal species on the study area during the fall, winter, and spring; however, their distribution, density, and use of habitats varied within seasons as well as seasonally. Mule deer demonstrated a widely-scattered distribution throughout the mixture of vegetation types west of Tract C-a during the summer. Other non-resident mule deer move in and through the study area in October. Mule deer occurred in all vegetation types but, as winter progressed, they moved from mixed brush to lower elevation sagebrush and pinyon/juniper-covered areas on Tract C-a and areas east of the tract where they overwinter. Mule deer returned gradually to the higher elevations in the spring.

A small number of elk (15-20) occurred in areas south and west of Tract C-a. Elk generally wintered in mixed brush at higher elevations than mule deer, but they were also observed in sagebrush and pinyon-juniper types during spring and fall. Elk have not been observed on Tract C-a but range throughout the western portion of the study area as well as adjacent areas to the north and south.

Wild horses occupy the study area throughout the year, generally within the area bounded by Big Duck Creek, Yellow Creek, Stake Springs Draw, and Cathedral Bluffs. It is estimated that the study area supports a minimum population of 135 horses.

The coyote and long-tailed weasel are the most abundant and consequently the most important mammalian predators in the study area. Indices of relative abundance calculated for the coyote and compared with federally-obtained indices from nearby sampling lines indicate that coyote populations are about average for the region and probably occur at the rate of 0.1 - 0.2 coyotes/km^2 on the study area. Long-tailed weasels are thought to occur at the rate of 0.5 - 0.7/km^2. Four other carnivorous mammals, the bobcat, badger, ermine, and skunk, were also documented in the study area, but the coyote is the only documented predator having the potential to affect big game.

A total of 139 species of avifauna was observed during baseline studies. Overall avian utilization of the study area is greatest during the summer periods. During both summers, the largest number of birds and the greatest species diversity were encountered within the riparian, agriculture, Douglas-fir, aspen, and all pinyon-juniper vegetation types. During June 1976, the rabbitbrush, sagebrush, mixed brush, and upland meadow vegetation types supported fewer species and lower total number of birds in comparison with the aforementioned types. Avian utilization of habitat types was generally greater in those habitats that exhibited greater foliage height diversity and plant species diversity.

Based on calculated importance values, the horned lark, scrub jay, blackcapped chickadee, mountain chickadee, robin, mountain bluebird, red-winged blackbird, green-tailed towhee, vesper sparrow, sage sparrow, dark-eyed junco, gray-headed junco, Brewer's sparrow, and song sparrow were determined to be the important songbird species of the dominant habitats on the study area. Of these 14 species, 12 species are breeding residents, 2 species are winter residents, and 7 species are year-round residents of the study area.

Three upland gamebird species inhabit the study area, including sage grouse, blue grouse, and mourning dove. Fourteen diurnal hawk, vulture, eagle, and falcon species, six nocturnal owl species, and the common raven are the raptor species that have been recorded on the study area. Nests of nine of the 21 species have been located on the study area. At least eight other species are expected to nest in the region.

One hundred fifty-nine reptiles representing four species of lizards and one snake species were observed during these surveys. The most abundant reptile species observed per unit of sampling effort was the sagebrush lizard (47 percent), followed closely by the tree lizard (42 percent). The sagebrush lizard was also the most widespread reptile on the study area, appearing in 84 percent of all transects for which reptiles were recorded. Habitats showing the highest abundance and diversity of reptiles were open, south-facing slopes with ledges and rock piles for basking and shelter and with a few scattered bushes and deadfall for additional refugia. The limited amount of this habitat in the study area results in a fairly low reptile population density and diversity averaged over the entire area. Several expected species were not discovered due to their absence or very low abundance in the study area.

Invertebrates were sampled in five of the most common vegetation types in the study area; bottomland sagebrush, north and south slope

pinyon-juniper woodlands, upland sagebrush, and mixed brush. A variety of sampling methods was used to identify the numerically abundant invertebrates within each vegetation type.

As required by the Oil Shale Lease Environmental Stipulations, fauna in the vicinity of Tract C-a was sampled for two years (October 1974 through October 1976) to inventory major faunal elements. Estimates or indices of abundance and diversity were produced for those animal groups where deriving such estimates was practicable. Major faunal elements surveyed included:

- Small mammals
- Large mammals
- Mammalian Predators
- Avifauna
- Reptiles and Amphibians
- Invertebrates

Sampling methodologies have been described in detail in previous reports, notably the RBOSP Terrestrial Annual Report (1976). Data have been presented throughout the project in quarterly progress reports. Those data are not repeated in detail here. Instead, the following sections will attempt to synthesize the results of the two-year data collection program into a comprehensive statement of existing population characteristics and interactions with a discussion of any trends or notable anomalies detected during the course of the terrestrial investigation. Since two years of study can be considered essentially point-in-time sampling, the existing literature base must be used to provide supplementary information to fill in gaps in the site-specific information for some animal groups. To the extent feasible, the interpretive text relies for its conclusions on the data actually collected by this program during this two-year investigation.

WILDLIFE INVENTORIES

The habitats sampled during the faunal investigations are listed in Table 3.24 along with their slope aspect and elevation.

TABLE 3.24

SITE DESCRIPTIONS FOR SMALL MAMMAL, AVIFAUNA AND INVERTEBRATE SAMPLING LOCATIONS FOR RBOSP

LOCATION DESIGNATION			Vegetation Type	Aspect/Elevation
Small Mammals	Avifauna	Invertebrates		
1	1		Agriculture	Flat/6300'
2	2		Upland sagebrush	Flat/6500'
3	3		Rabbitbrush	Flat/6800'
4	4		Pinyon-juniper-mixed brush	North/7400'
5	5	5	Mixed brush	North/7200'
6	6		Pinyon-juniper-sagebrush	Flat/7400'
7	7		Bald	Flat/8500'
A	8	1	Bottomland sagebrush	Flat/6400'
B	9	2	Pinyon-juniper	South/7000'
C	10	3	Pinyon-juniper	North/6900'
D	11	4	Upland sagebrush	North/7100'
E	12		Mixed brush	South/8300'
F	13		Douglas-fir	North/8200'
G	14		Aspen	North/8100'
	15		Riparian	Flat/6700'

I. SMALL MAMMALS

The small mammal census program was designed to identify the species of small mammals that occur within Tract C-a and the contiguous area, to describe and determine the factors regulating their distribution and abundance in dominant habitats, and to aid in developing a designation of important species. Seasonal periodicity of activity, reproductive effort, and trophic relationships are described. Small mammal average weights and habitat affinities were determined, and species diversity values calculated for the various habitats. Finally, some interrelationships of small mammals with their environment are elucidated.

Small mammals are an important consumer group in the Piceance basin ecosystem and form a major pathway in the transfer of energy from primary producers (i.e., vegetation) and other consumers (e.g., invertebrates) to secondary consumers (e.g., predators) and decomposers (e.g., bacteria). Other ways in which small mammals may play an important role in the Piceance basin ecosystems include:

- Direct destruction of green leaves, stalks, or shoots with an impact on photosynthesis
- Destruction of seeds with an impact on the number of progeny surviving to the next growing season
- Movement of seeds through the habitat in seed caches or by consumption and defecation
- Feeding on the bark at the ground surface or on roots resulting in the death of plants
- Movement of nutrients in the system through defecation, through storage of food or by concentration of activity at a site
- Reconstruction of the habitat by burrowing, tunnelling, and other earth-moving activities
- Serving as a reservoir for parasites and diseases of other consumers including man
- Serving as a buffer to predation of other consumers

The presence of 30 species of small (and medium-sized) mammals was documented by live, removal, and pitfall trapping, night spotlight censusing, mist netting

(for bats), and opportunistic observations in the vicinity of Tract C-a (Table 3.12 in RBOSP Progress Report 10 1977). Data collected during live-trapping operations from over 6,300 individuals have permitted the formulation of several generalizations concerning the distribution and abundance of small mammal populations among major habitats within the area of investigation.

A. Distribution and Abundance

Vegetation, specifically the amount and kind of vegetation, is the most important factor controlling the distribution and abundance of small mammal populations in the vicinity of Tract C-a, but elevation also appears to be an important controlling factor for some species. Within habitats sampled below 8,000 feet, the amount of shrub cover appears to be the most important factor regulating the abundance of small mammals, although other factors such as plant species composition, substrate condition, slope and aspect may play a role. The largest number of small mammals captured per unit trapping effort (i.e., individuals/100 trap nights) occurred in rabbitbrush, pinyon-juniper/mixed brush, and mixed brush (Grid 5) (Table 3.25). Vegetation data collected from permanent phytosociological transects on or near small mammal grids showed that these habitats were ranked 3, 2, 5, 6, and 1 in percentage of shrub cover of all sampled habitats below 8,000 feet (Table 3.26). Accordingly, the habitat with the fewest captures below 8,000 feet, bottomland meadow, also exhibited the lowest shrub cover.

Aspen and Douglas-fir contained fewer small mammals than all sampled habitats except bottomland meadow even though they exhibited the highest shrub cover of all habitats. The harsher environmental conditions and the accompanying lower productivity caused by a shorter growing season characteristic of elevations above 8,000 feet are probably the major limiting factors to small mammal abundance here. Vegetation species composition and kinds of food available may be additional factors.

With the exception of the bald vegetation type, the habitats above 8,000 feet (aspen, Douglas-fir, and mixed brush) revealed the same general trend as evident at lower elevations, with more small mammals being encountered in habitats with a higher shrub cover. However, the high trapping success at the bald habitat

TABLE 3.25

SMALL MAMMAL TRAPPING SUMMARY FOR ALL GRIDS DURING EACH SAMPLING PERIOD FOR RBOSP

Grid/Vegetation Type	Individuals captured of all species per 100 trap nights											
	Oct. 1974	Dec. 1974	May 1975	July 1975	Sept. 1975	Dec. 1975	May 1976	July 1976	Sept. 1976	Average	%RA	Rank
1 Bottomland meadow	10.91	14.55	6.67	5.05	3.64	0.61	3.03	30.91	15.76	10.36	4.36	14
2 Upland sagebrush	10.91	4.85	13.33	20.61	17.58	1.21	17.58	37.58	23.64	16.36	6.88	9
3 Rabbitbrush	23.64	15.15	35.76	12.73	23.03	3.64	24.85	39.83	34.55	24.37	10.25	1
4 P-J/mixed brush	24.24	2.42	22.42	13.33	12.73	6.06	30.91	38.18	26.67	19.66	8.27	4
5 Mixed brush	20.61	1.21	23.03	8.48	33.33	0.00	23.64	35.76	29.70	19.53	8.21	5
6 P-J/sagebrush	18.18	6.06	21.21	15.15	13.94	3.64	24.85	34.20	35.15	19.79	8.33	3
7 Bald	5.45	0.00	9.09	8.48	9.70	9.70	12.73	60.61	13.94	16.38	6.89	8
A Bottomland sagebrush	22.26	12.73	12.33	12.63	26.47	2.42	14.89	38.35	27.52	21.10	8.88	2
B P-J (South Slope)	16.54	9.09	14.14	16.09	14.44	5.45	14.59	26.32	22.71	17.13	7.21	7
C P-J (North Slope)	15.04	1.21	9.02	14.59	11.28	2.42	13.83	31.73	22.41	15.85	6.67	10
D Upland sagebrush	15.34	1.21	9.77	7.97	6.47	0.61	14.14	30.33	19.85	14.34	6.03	11
E Mixed brush	8.57	0.00	13.08	11.13	17.44	6.06	14.59	44.68	11.73	17.81	7.49	6
F Douglas-fir	8.98	7.88	8.52	7.21	8.85	4.85	8.52	29.84	13.44	11.48	4.83	13
G Aspen	*	*	10.49	6.56	10.49	6.67	13.44	29.18	15.08	13.58	5.71	12
Average	15.39	5.87	12.40	11.39	14.17	3.33	14.38	34.04	20.24	16.95		
% Relative Abundance	11.73	4.48	9.45	8.68	10.80	2.54	10.96	25.95	15.42			
Rank	3	8	6	7	5	9	4	1	2			

*Grid not sampled.

TABLE 3.26

PERCENT COVER OF TREE, SHRUB AND HERBACEOUS VEGETATION ON OR NEAR EACH SMALL MAMMAL LIVE TRAPPING GRID AS DETERMINED FROM DATA COLLECTED ON PERMANENT PHYTOSOCIOLOGICAL TRANSECTS FOR RBOSP

Grid	Vegetation Type	% Cover-all vegetation species			
		Tree	Shrub	Herbaceous1/	Total
1	Bottomland meadow 2/	--	0.3	67.9	65.2
2	Sagebrush 2/	--	21.4	7.3	28.8
3	Rabbitbrush 3/	--	35.5	23.0	58.5
4	Pinyon-juniper/mixed brush 2/	1.8	24.3	10.5	36.5
5	Mixed brush 2/	--	51.3	8.5	59.8
6	Pinyon-juniper/sagebrush 2/	--	25.8	25.9	51.6
7	Upland meadow 2/	--	--	20.9	20.9
A	Greasewood-sagebrush 3/	--	39.9	9.4	49.3
B	Pinyon-juniper (south slope) 3/	13.0	1.4	3.6	18.0
C	Pinyon-juniper (north slope) 2/	28.5	1.0	1.8	31.3
D	Sagebrush 3/	--	33.0	13.4	46.4
E	Mixed brush 2/	--	74.4	5.8	80.2
F	Douglas Fir 3/	30.5	57.0	20.7	108.1
G	Aspen 3/	34.9	59.4	26.2	120.6

1/Average of 3 sampling periods (March, July, and September, 1975).
2/Vegetation transect is within a comparable vegetation type near the small mammal grid.
3/All or a portion of the vegetation transect is within the small mammal grid.

type, which is characterized by little or no shrub cover, may not be indicative of a real departure from this established trend. The increased trapping success at the bald site during the second year of investigation coincided with and resulted from a large increase of deer mouse population levels. Since the sampled bald habitat is a limited type surrounded by mixed brush habitat, it is likely the increase in trapping success resulted from surplus deer mice emigrating from the mixed brush type. It is improbable that the bald type, exposed to the harsh conditions of the high elevation and with little shrub cover, could support the population levels indicated by the trapping results.

Species diversity, as indicated by the Shannon-Weiner index, which accounts for both the number of species and the relative number of individuals of each species, seems to be tied closely to the presence or absence of trees (pinyon and juniper) in habitats below 8,000 feet. Of the larger (7.29 ha) grids, the two that consistently showed the highest diversity were the two established within pinyon-juniper woodlands, Grid B (pinyon-juniper/south slope) and Grid C (pinyon-juniper/north slope) (Table 3.27). Likewise, Grid 4 (pinyon-juniper/mixed brush) had the highest species diversity of the 0.81 ha grids. Pinyon and juniper trees provide food for many small mammal species that eat the highly nutritious pinyon nuts and juniper berries. The latter are more consistently available than pinyon nuts because they remain on trees a large part of the year and are not so completely destroyed by insects as pinyon nuts (Frischknecht 1975). The cambium of pinyon may also be eaten by certain species and the shreddy bark of juniper is often used in nest building (Frischknecht 1975).

The value of pinyon and juniper trees as a source of food and potential nesting sites is further demonstrated by the fact that eight of the 14 species encountered during all live-trapping operations inhabited pinyon-juniper woodlands (Table (3.28). In fact, three of the species, piñon mouse, Colorado chipmunk, and the bushy-tailed woodrat, were generally limited to this vegetation type. Another species, the golden-mantled ground squirrel, was caught almost exclusively on grids established within or adjacent to pinyon-juniper woodlands.

The concepts of species diversity and total abundance were combined in a rating

TABLE 3.27

SHANNON-WEINER DIVERSITY INDICES (H') FOR ALL SMALL MAMMAL GRIDS DURING EACH SAMPLING PERIOD FOR RBOSP

Designation	Vegetation Type	Sample Period								
		1 Oct. 1974	2 Dec. 1974	3 May 1975	4 July 1975	5 Sept. 1975	6 Dec. 1975	7 May 1976	8 July 1976	9 Sept. 1976
1	Bottomland meadow	0.349	0.803	0.908	0.500	0.000	0.000	0.000	0.892	1.114
2	Upland sagebrush	0.687	0.000	0.967	1.047	0.718	0.693	0.401	1.185	0.986
3	Rabbitbrush	0.745	0.440	0.894	0.619	0.455	0.000	0.625	0.678	0.692
4	Pinyon-juniper/ mixed brush	0.980	0.000	1.001	1.038	0.971	0.000	0.860	1.141	0.871
5	Mixed brush	0.665	0.693	0.642	0.683	0.655	0.000	0.540	0.942	0.469
6	Pinyon-juniper/ sagebrush	0.673	0.000	0.935	1.133	0.295	0.451	0.730	1.189	1.143
7	Bald	0.349	0.000	0.500	0.520	0.000	0.000	0.000	0.510	0.826
A	Bottomland sagebrush	0.950	0.773	0.849	1.040	0.970	1.040	0.793	0.828	0.923
B	Pinyon-juniper (south slope)	1.182	0.393	1.440	1.634	1.296	0.349	1.527	1.312	1.376
C	Pinyon-juniper (north slope)	1.231	0.693	1.331	1.477	1.314	0.562	1.042	1.237	1.288
D	Upland sagebrush	0.981	0.000	0.998	1.165	0.721	0.000	1.003	0.920	0.825
E	Mixed brush	0.857	0.000	1.046	1.137	0.764	0.000	0.645	0.976	0.751
F	Douglas-fir	0.398	0.271	0.645	0.693	1.147	0.693	0.963	0.904	1.352
G	Aspen	1.028	0.491	0.810	0.613	1.245	0.908	0.901	1.074	1.256

TABLE 3.28

SMALL MAMMAL TRAPPING SUMMARY BY SPECIES

FOR ALL GRIDS DURING ALL WARM-WEATHER SAMPLING PERIODS[1/] FOR RBOSP

Grid/Vegetation Type	Number of individuals captured of each species[2/] per 100 trap nights													
	SOME	SOCI	SPLA	SPTR	PEAM	EUMI	EUQU	PEMA	PETR	NECI	CLGA	MIMO	MILO	LACY
1 Bottomland meadow	0.0	0.0	0.0	0.0	0.0	1.6	0.0	7.8	0.0	0.0	0.0	1.6	0.1	0.2
2 Upland sagebrush	0.0	0.0	0.2	3.55	0.1	9.1	0.0	7.3	0.0	0.0	0.0	0.0	0.0	0.0
3 Rabbitbrush	0.0	0.0	0.5	0.0	0.0	12.5	0.0	15.2	0.0	0.0	0.0	0.0	0.2	0.0
4 Pinyon-juniper/mixed brush	0.0	0.0	0.9	0.0	0.2	12.3	2.9	7.8	0.0	0.0	0.0	0.0	0.0	0.0
5 Mixed brush	0.0	0.0	0.4	0.0	0.0	17.2	0.4	6.9	0.0	0.0	0.0	0.0	0.0	0.0
6 Pinyon-juniper/sagebrush	0.0	0.0	0.7	0.0	0.3	8.0	1.8	12.9	0.1	0.0	0.0	0.0	0.1	0.0
7 Bald	0.0	0.0	0.1	0.0	0.0	3.4	0.0	16.0	0.0	0.0	0.0	0.0	0.0	0.1
A Bottomland sagebrush	0.0	0.0	0.7	0.0	0.1	11.7	0.3	8.6	0.0	0.0	0.0	0.0	0.5	0.0
B Pinyon-juniper (south slope)	0.0	0.0	1.8	0.0	0.2	7.9	2.0	4.5	0.9	0.6	0.0	< 0.1	0.0	0.0
C Pinyon-juniper (north slope)	0.0	0.0	1.3	0.0	< 0.1	5.4	2.2	7.1	0.5	0.2	0.0	< 0.1	0.0	0.0
D Upland sagebrush	0.0	< 0.1	1.2	0.0	0.0	5.8	<0.1	7.9	<0.1	0.1	0.0	0.0	0.0	0.2
E Mixed brush	0.0	0.0	0.9	0.0	0.0	7.5	0.1	9.9	0.0	0.0	<0.1	0.0	0.2	0.3
F Douglas-fir	0.0	0.0	0.0	0.0	0.0	4.2	0.8	3.6	0.0	0.0	3.7	0.0	0.1	0.0
G Aspen	0.1	0.0	0.0	0.0	0.0	3.3	0.2	5.9	0.0	0.0	4.6	0.0	0.3	0.0
Average	< 0.1	< 0.1	0.9	0.1	0.1	7.6	0.8	8.0	0.2	0.1	0.5	0.1	0.1	0.1
% Relative Abundance	< 0.1	< 0.1	4.6	0.6	0.3	41.0	4.6	43.4	1.0	0.6	2.5	0.3	0.7	0.4

1/ Winter sampling periods deleted from analysis due to the inactivity of most small mammal species during this time.

2/ See Table 3.12 for species represented by each 4-letter code.

system to determine the relative importance of each sampled habitat to small mammal populations. In general, habitats at lower elevations with a high shrub and/or tree cover rated highest; in order of their importance to small mammal populations these habitats were bottomland sagebrush, pinyon-juniper/ sagebrush, and rabbitbrush. Habitats at higher elevations, mixed brush, upland sagebrush, Douglas-fir, and aspen, rated lower. Habitats with no shrub cover, bottomland meadow and bald, rated lowest.

Seasonal trapping success of small mammal species over all habitats was characterized by several trends (Figure 3.15 in RBOSP Progress Report 10 1977). Population levels were low in the spring, increased throughout the summer and dropped drastically during the winter. Furthermore, a significant increase in total population levels occurred during 1976 investigations. Low population levels in the spring result primarily from a high mortality due to harsh environmental conditions and lack of recruitment of new individuals (through reproduction) during the winter. Reproduction information obtained from the deer mouse, least chipmunk, and the longtailed vole indicates that the peak of the reproductive season occurs approximately mid-July with the resulting recruitment of new, trappable individuals being evidenced by increased trapping success (hence population levels) during late summer. A low trapping success during winter is affected primarily by the reduced activity of trappable small mammals. The increased small mammal abundance seen in 1976 resulted from population increases for 7 of the 14 species encountered.

B. Species Importance

Abundance was established as the main indicator of species importance. In this regard the deer mouse and least chipmunk, accounting for 43.4 and 41 percent, respectively, of the total trappable small mammal figure, are by far the most important species in the vicinity. These species were well represented in each sampled habitat and were the two most abundant small mammals in all habitats except aspen and Douglas-fir where the red-backed vole predominant (Table 3.28).

As a result of their high population levels and similar distribution patterns, the potential for competition between the least chipmunk and deer mouse is great, especially since they exhibit almost identical food preferences.

However, they appear to avoid competitive interaction by utilizing different activity periods--the deer mouse is nocturnal while the least chipmunk is diurnal--and by different utilization of habitats. Both species revealed a definite affinity, as determined by chi-square values, for four habitats (total of eight) (Table 3.29). However, only one habitat was common to both species and five of the six other habitats were characterized by opposite affinities for the two species. The deer mouse was more common in habitats with a high shrub cover while high population levels of the least chipmunk were more closely associated with pinyon-juniper habitat.

The golden-mantled ground squirrel and the Colorado chipmunk, though not nearly as abundant as either the least chipmunk or the deer mouse, were the third most frequently-captured small mammals, accounting for about 4.6 percent each of the total abundance. Both species indicated a definite affinity for pinyon-juniper woodlands as did two other species, the pinon mouse (1 percent relative abundance), and the bushy-tailed woodrat (0.6 percent).

The other eight trappable small mammal species were captured rather infrequently and accounted for only 5.0 percent of the total abundance. However, some species were predominant in certain habitat types and a definite pattern of macrohabitat preferences was discernible for most. Captures of the thirteen-lined ground squirrel were limited to the grid established in upland sagebrush vegetation on 84 Mesa; and, accordingly, the species showed a definite affinity for this habitat. The Apache pocket mouse was captured within five different types but showed an affinity for pinyon-juniper woodlands.

Of the four vole species, the red-backed vole was the most abundant. It is adapted for living at elevations above 8,000 feet (Lechleitner 1969) and was a predominant small mammal in both Douglas-fir and aspen vegetation. The montane vole showed a definite affinity for bottomland meadow while its cogener, the long-tailed vole, indicated an affinity for bottomland sagebrush. The sagebrush vole as its name implies revealed a preference for upland sagebrush as well as for mixed brush.

TABLE 3.29

DETERMINATION OF MACROHABITAT AFFINITIES BY CHI-SQUARE VALUES[1/]
FOR ALL SPECIES CAPTURED ON EACH GRID
DURING ALL WARM-WEATHER SAMPLING PERIODS[2/] FOR RBOSP

		Species													
Grid/Vegetation Type		SOME	SOCI	SPLA	SPTR	PEAP	EUMI	EUQU	PEMA	PETR	NECI	CLGA	MIMO	MILO	LACY
1	Bottomland meadow	0.03-	0.03-	9.28-	1.25-	0.64-	51.95-	9.16-	0.06-	2.04-	1.16-	4.96-	466.56+	0.16-	1.85+
2	Upland sagebrush	0.03-	0.03-	6.25-	1190.00+	0.15+	3.53+	9.71-	0.78-	2.16-	1.23-	5.26-	0.61-	1.58-	0.84-
3	Rabbitbrush	0.03-	0.03-	1.86-	1.40-	0.72-	39.68+	10.27-	79.56+	2.29-	1.30-	5.56-	0.65-	0.06+	0.89-
4	Pinyon-juniper/mixed brush	0.03-	0.03-	0.01+	1.32-	2.58+	34.04+	60.74+	0.07-	2.16-	1.23-	5.26-	0.61-	1.58-	0.84-
5	Mixed brush	0.03-	0.03-	3.47-	1.32-	0.68-	142.33+	2.29-	1.69-	2.16-	1.23-	5.26-	0.61-	1.58-	0.84-
6	Pinyon-juniper/sagebrush	0.03-	0.03-	0.19-	1.40-	15.05+	0.23+	13.41+	35.85+	0.72-	1.30-	5.56-	0.65-	0.27-	0.89-
7	Bald	0.03-	0.03-	8.50-	1.40-	0.72-	28.62-	10.27-	96.62+	2.29-	1.30-	5.56-	0.65-	1.67-	0.01+
A	Bottomland sagebrush	0.13-	0.13-	1.48-	5.33-	0.03+	106.34+	13.68-	2.13+	8.71-	4.94-	21.20-	2.47-	80.35+	3.38-
B	Pinyon-juniper (south slope)	0.13-	0.13-	45.19+	5.33-	14.39+	0.52+	74.10+	70.24-	119.65+	98.46+	21.20-	0.88-	6.37-	3.38-
C	Pinyon-juniper (north slope)	0.13-	0.13-	10.43+	5.33-	0.20-	28.04-	107.46+	4.47-	26.82+	1.89+	21.20-	0.88-	6.37-	3.38-
D	Upland sagebrush	0.13-	5.61+	6.44+	5.48-	2.81-	20.16-	29.16-	0.08-	7.07-	0.85-	21.80-	2.54-	6.55-	5.88+
E	Mixed brush	0.14-	0.14-	0.01+	5.64-	2.89-	0.08-	37.48-	21.88+	9.21-	5.22-	18.59-	2.61-	1.58+	36.52+
F	Douglas-fir	0.06-	0.06-	17.68-	2.38-	1.22-	31.27-	0.12-	51.14-	3.88-	2.20-	482.94+	1.10-	1.19-	1.51-
G	Aspen	17.61+	0.05-	15.59-	2.10-	1.07-	44.53-	9.97-	10.68-	3.43-	1.94-	687.08+	0.97-	2.48+	1.33-
	Total	18.56	6.48	126.36	1229.68	43.14	531.32	387.81	375.26	192.59	124.24	1311.42	481.79	111.82	61.54

1/ A total chi-square value greater than 22.36 indicates a nonrandom distribution (i.e., affinity for certain types) at the 95% confidence level. The sign following each number denotes whether the observed number of captures is greater (+) or less than (-) the expected.

2/ Winter sampling period deleted from analysis due to inactivity of most small mammal species during this time.

C. Other Population Parameters

Average body weight determinations (Figure 3.17 in RBOSP Progress Report 10 1977) revealed or suggested several trends for the small mammal species encountered. Females consistently weighed more than males. This difference was accentuated in the spring when a number of pregnant females were included in the samples. Body weights decreased over the summer, most probably the result of the recruitment (through reproduction) of new, lighter-than normal young adults. Body weights for active small mammals were lowest during the winter, perhaps reflecting a reduced food supply and a greater energy output during cold weather.

Several well-documented trends concerning small mammal ranges appeared to be supported by the live-trapping data (Tables 3.58 and 3.59 in RBOSP Progress Report 10 1977). Males generally travel farther than females in their search for food, mates, and in defense of territories (Hayne 1949). Accordingly, a large range length and a higher representation in samples (since they would encounter more traps) for males would be expected and in fact was documented by the data. Also, animals tend to have larger home ranges in habitats with low productivity (Pianka 1971). Data for the deer mice supported this generalization: its highest average range length occurred in pinyon-juniper (north slope), which was characterized by the lowest combined shrub-herbaceous cover of all habitats sampled.

Studies of the food habits of the deer mouse, least chipmunk, and long-tailed vole (Table 3.40 in RBOSP Progress Report 10 1977) characterized all three species as omnivorous, opportunistic feeders. The deer mouse and least chipmunk utilized seeds to a great extent while the long-tailed vole preferred succulent vegetation. All species, however, switched to other food sources when these became more abundant. For example, the least chipmunk and deer mouse both showed an increased utilization of succulent vegetation in the spring when it was more available. Conversely, seeds were used extensively during the winter. Furthermore, both species showed the highest utilization of seeds at the pinyon-juniper/north slope habitat which supported the lowest herbaceous (i.e., succulent vegetation cover.

D. Other Investigations

Small mammals not taken by live trapping were documented by other methods. Pitfall traps, established in all major habitats, revealed the presence of both the northern pocket gopher and the wandering shrew. A cottontail and two species of jackrabbits, the white-tailed jackrabbit and the black-tailed jackrabbit, as well as the porcupine, were documented during the night spotlight censuses. The censuses confirmed information obtained from the Colorado Division of Wildlife that lagomorph population levels in the Piceance basin are presently low but increasing.

The presence of six species of bats was revealed by mist netting during baseline investigations. The species documented were the California myotis, longeared myotis, big brown bat, hoary bat, and the silver-haired bat.

II. LARGE MAMMALS

The objectives of the large mammal study were to determine the distribution and relative abundance of mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), and wild or feral horses (*Equus caballus*) in the vicinity of Tract C-a on a seasonal basis; to determine relative use of portions of the study area seasonal movements of mule deer; and to describe large herbivore-range resource interactions based on observations and data gathered during the large mammal and range investigations.

Non-domestic large mammals in the area include mule deer, elk, and wild horses. Each is discussed in an individual section, and an additional section is devoted to a discussion of the interrelationships affecting these large mammals. Unless specifically stated otherwise, "deer" refers to mule deer and "horses" refers to wild or feral horses.

A. Mule Deer

Mule deer activity on the study area varies seasonally. As on Tract C-b, (C-b Shale Oil Project 1976), summer was the season when the lowest number of mule deer occupied the study area. Tract C-a and areas east of Tract C-a and areas east of Tract C-a contained a few mule deer during the summer, but the scattered animals and tracks were infrequently observed during summer field activities. Pellet

group survey results also indicate the scarcity of mule deer on Tract C-a during the summer (Figure 3.3). Transects on Tract C-a and one transect bordering Tract C-a on the south had no pellet groups during either summer. Transects north of Tract C-a also demonstrated a low pellet group index for both summers.

Most mule deer remaining on the study area during the summer were scattered throughout the areas of higher elevation west of Tract C-a. Mule deer numbers were low, and their distribution was scattered, hence density estimation was not feasible for the summer seasons. The mixture of aspen, Douglas-fir, sagebrush, and mixed brush vegetation types, combined with the range of slope steepness and aspects occurring west of Tract C-a, affords a variety of microhabitats for mule deer. Eighty-five to 92 percent of the pellet groups accumulated during both summers were located in the mixed brush vegetation type west of Tract C-a (Figure 3.4). In addition, 46 percent of all plots sampled also occurred within the mixed brush vegetation type, which is the most common vegetation type west of Tract C-a. These data are consistent with the fact that range production and utilization investigations indicate that the mixed brush type produced the highest amount of forage and also received heavy forage use during the summer. Few pellet groups were tallied in the other vegetation types during the summer.

Mule deer did not exhibit a preference for any particular aspect of slopes during the summer (Figure 3.5). Although no pellet groups were found on plots located on flat or northeast-facing slopes, the percentage of pellet groups found on other aspects varied widely during the two summer sampling periods. Similar variation also existed in the slope gradient data gathered during the summer periods, hence a preferred slope gradient was not evident either (Figure 3.6). Variability may be due to the small number of pellet groups tallied, and the low number and scattered distribution of mule deer in the area during the summer, as well as to the possibility that mule deer seek a variety of macroenvironments in response to everchanging environmental conditions throughout the summer.

Kufeld at al. (1973) reported average mule deer summer diets consisting of 49 percent browse, 46 percent forbs, and 3 percent grasses and grasslike plants. The vegetation types occurring at higher elevations are generally more diverse

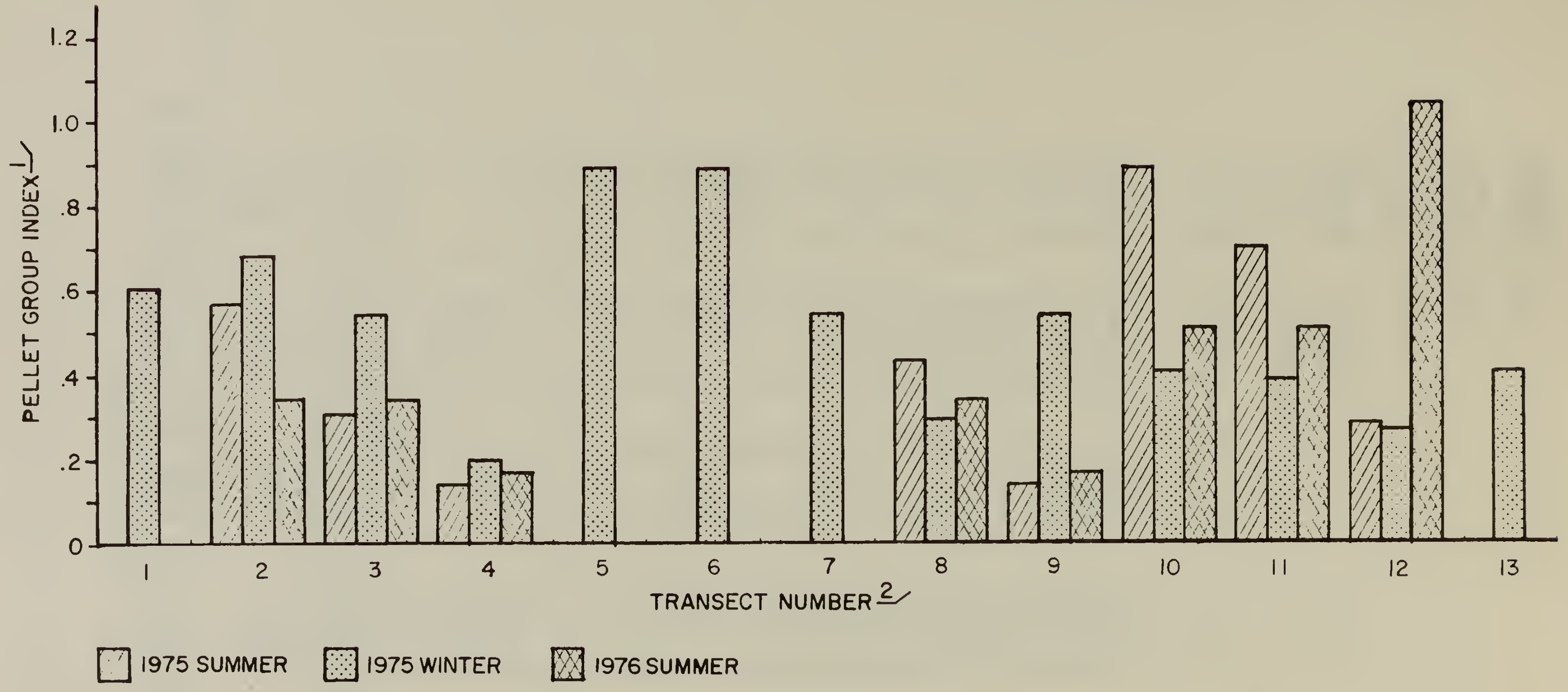


Figure 3.3

RESULTS OF PELLET-GROUP COUNTS FOR THREE SEASONS (1975-1976) ON 13 TRANSECTS FOR RBOSP

1/ Pellet group index equals the pellet groups per acre accumulated divided by the number of days in the accumulation period.

2/ Transects 1,5,6, and 7 located on Tract C-a; transects 9 and 13 on the northern and southern borders: remaining transects scattered within two miles west of Tract C-a (exact location shown in Figure 3-7-36, RBOSP 1976).

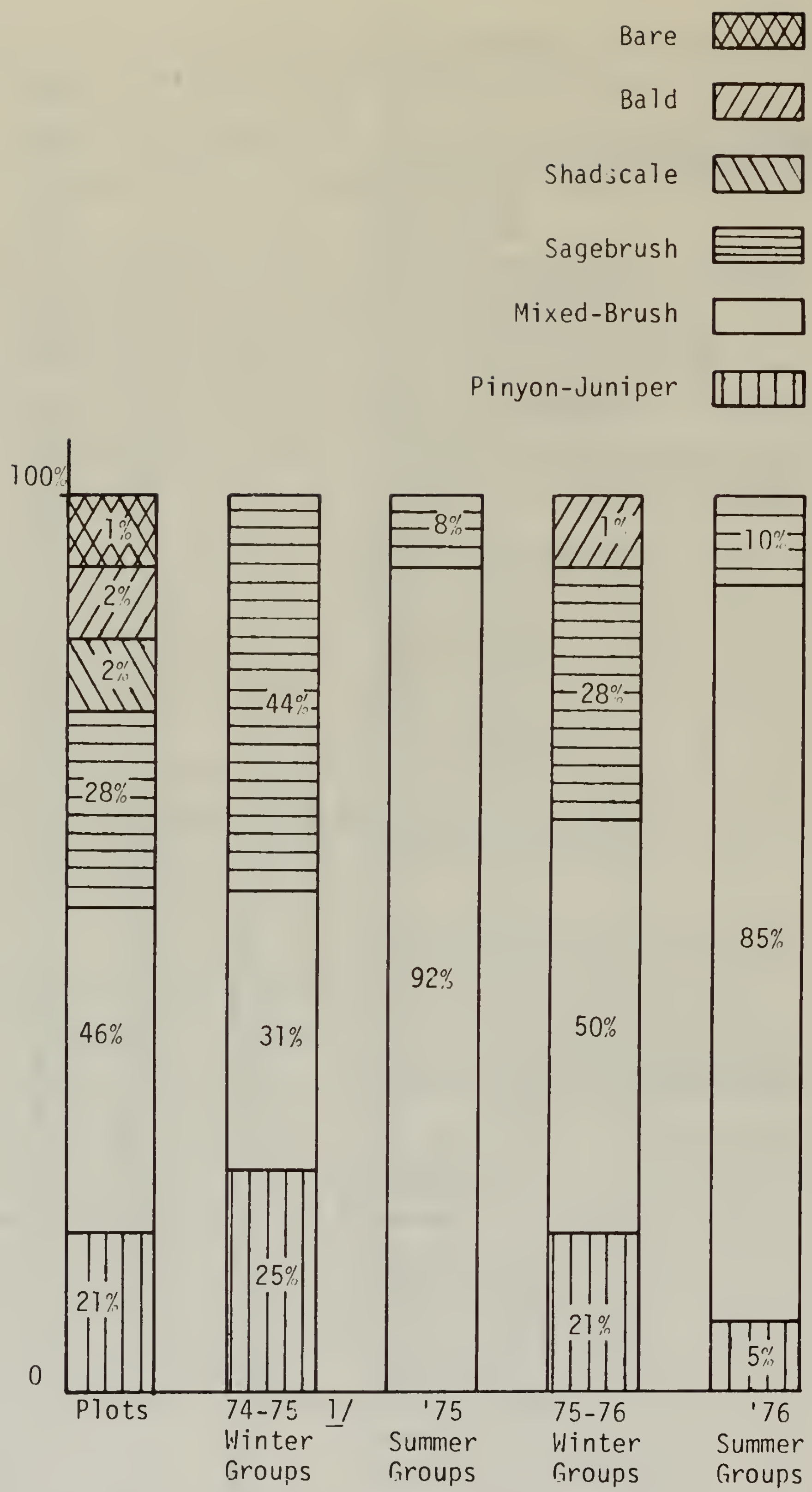


FIGURE 3.4
DISTRIBUTION OF PELLET GROUP PLOTS AND PELLET GROUPS ON SIX VEGETATION TYPES DURING FOUR SEASONS (1974-1976) ON 13 TRANSECTS FOR RBOSP.

1/Based on 4 transects located on Tract C-a.

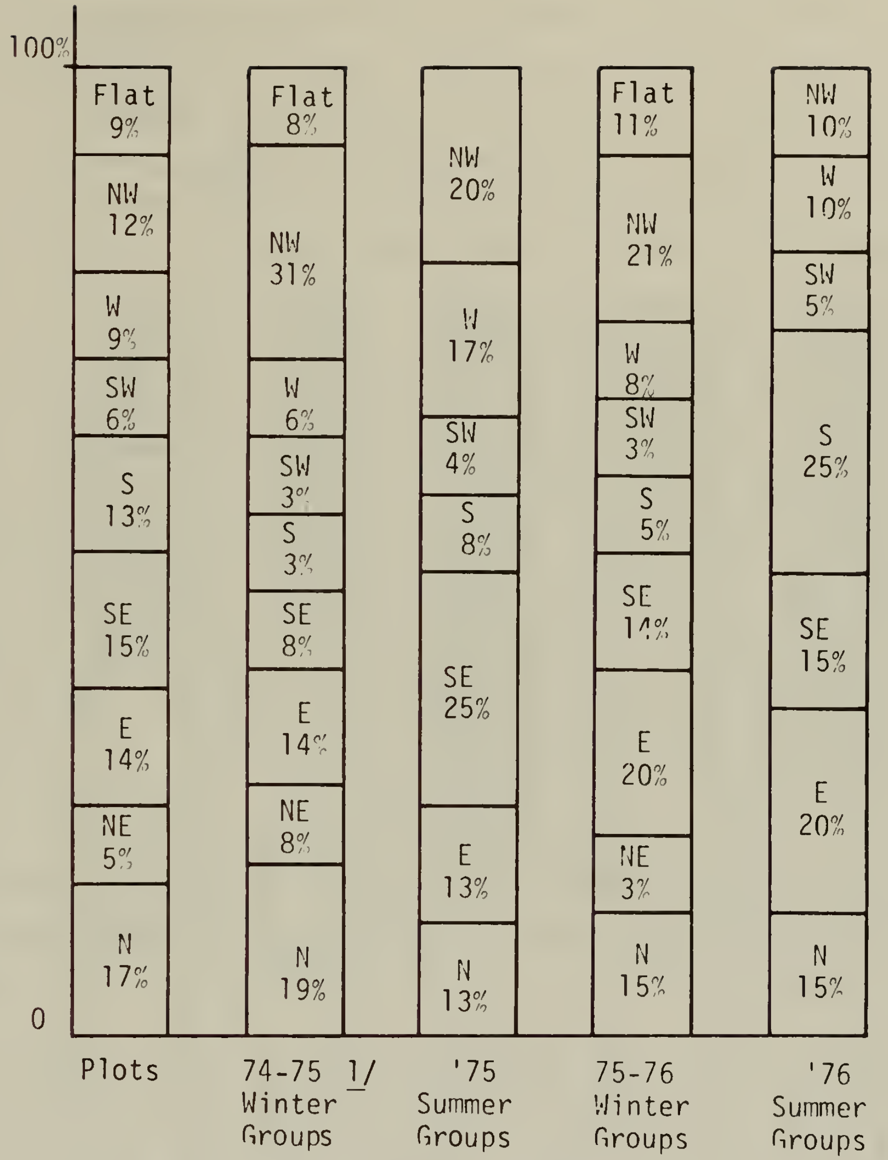


FIGURE 3.5
DISTRIBUTION OF PELLET-GROUP PLOTS AND PELLET GROUPS BY SLOPE ASPECT DURING FOUR SEASONS (1974-1976) ON 13 TRANSECTS FOR RBOSP

1/Based on 4 transects on Tract C-a.

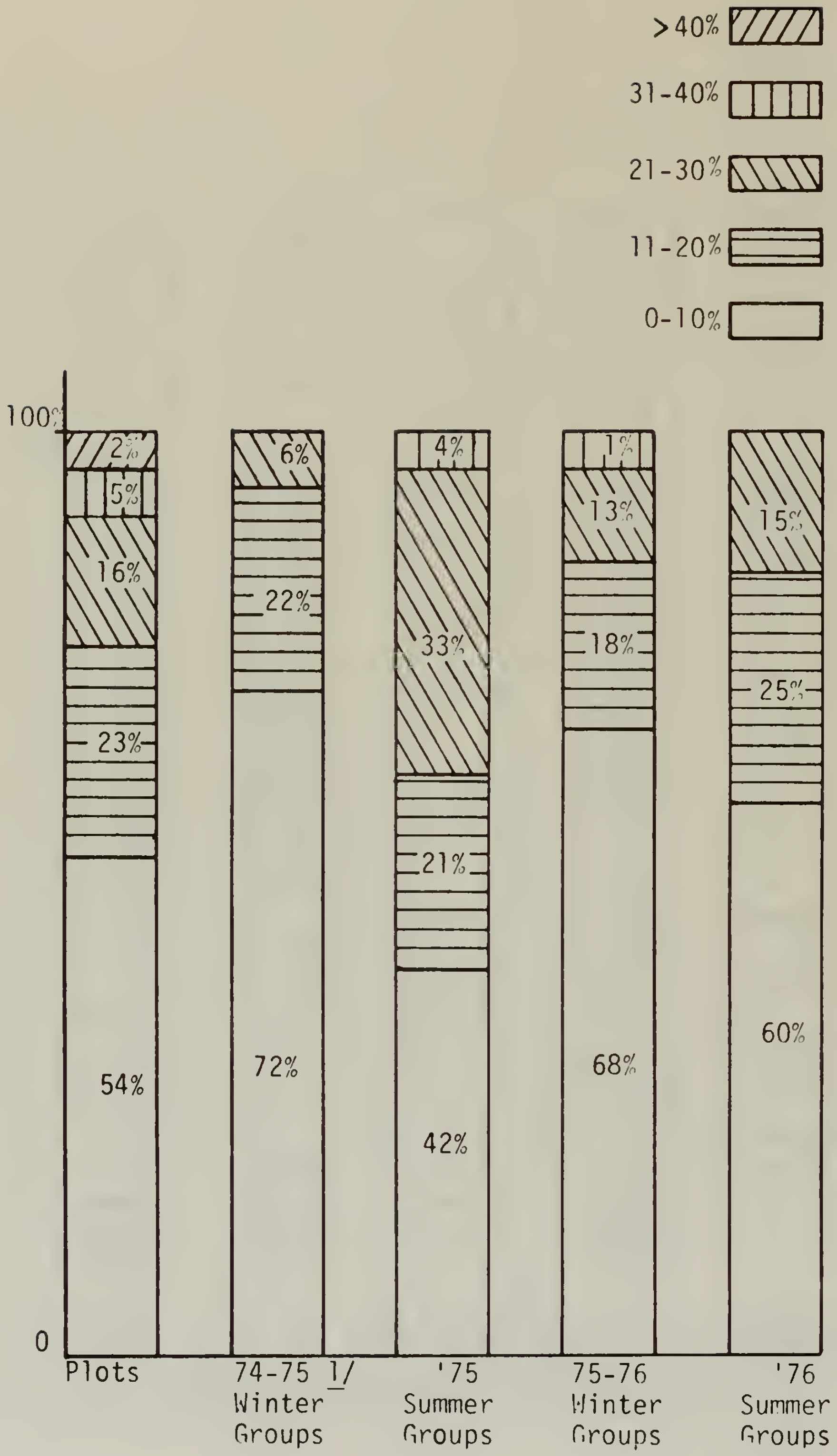


FIGURE 3.6
DISTRIBUTION OF PELLET GROUP PLOTS AND PELLET GROUPS BY SLOPE GRADIENT DURING FOUR SEASONS (1974-1976) ON 13 TRANSECTS FOR RBOSP

1/Based on 4 transects located on Tract C-a.

and productive than the types on the lower elevations of the study area. And, accordingly, mule deer on the study area in the summer occupy such higher elevations, where they take advantage of the more desirable conditions in terms of quantity and diversity of forage. The higher elevations are probably also attractive during summer due to their relatively cooler temperatures. Water is available at springs, streams, and stock watering ponds in the bottoms of gulches at the higher elevations. Water sources include Water and Spruce Gulch, Stake Springs, Cottonwood Spring, Maverick Spring, and Duck Creek.

In October, mule deer start to move into and through the study area to winter ranges. The environmental, physiological, and/or psychological factors initiating this migratory movement are not clearly understood; however, movements are often correleated with a drop in temperature, snowfall, or a combination of the two factors (Loveless 1967; Richens 1966; Russell 1932). Some mule deer move into the Tract C-a area before snow at the higher elevations is deep enough to hamper activity, while other deer seem to remain at the highest elevation possible and only move far enough to stay out of snow depths which hamper activities. Snow depth of 12 inches does hamper mule deer use of most areas (Loveless 1967; Gilbert et al. 1970). Mule deer on the U-a/U-b tracts apparently move between areas in response to temperature differences as little as 5 F during fall and winter periods (VTN Colorado 1976). Whatever the cause of the movement, the main consideration is that a change in range occurs with the change of the seasons.

Mule deer movements into and through the study area start in October and appear to continue throughout the entire winter as animal density and areas of activity change. Trail counts and aerial surveys (Figure 3.24 and Table 3.63 in RBOSP Progress Report 10 1977) that mule deer moved from the south and west of Tract C-a to areas north and east of the study area during fall and early winter. Movements continue throughout the winter and into spring when animals move into summer range. Mule deer occur on all vegetation types, but as winter progresses, most move from mixed brush types to sagebrush and pinyon-juniper covered areas on Tract C-a and areas east of Tract C-a, where the animals range until returning to the higher elevations in the spring. An area used at one time may not be used at another for a multitude of reasons, such as

forage palatability, wind speed, temperature, slope aspect, cover availability, etc. Many deer foraged in the open bottomland meadows during the spring. The spring migration appeared to be a gradual dispersion from areas heavily used during the winter and early spring. None of the ridges, slopes, or gulches are avoided during movements in the area. Bottomland meadows were used more during spring than during fall movement periods.

A very small portion of the study area, such as isolated steep cliffs in Box Elder Gulch, could present a barrier to mule deer movement. However, most sections of the study area can be easily traversed by mule deer, thus precluding a migration route dictated by topographical characteristics. Mule deer appear to use most portions of the area during at least part of the seasonal movements but take advantage of topographical and man-made features which were present. Many of the tracks along the road count route crossed the road where gates were open or old fences were down. Tracts often followed the road for a short distance; animals frequented the cleared zone along the pipeline south of Tract C-a. On 84 Mesa most tracks occurred in areas where small valleys or gulches crossed the road. Numerous tracks were also located in scattered pinyon-juniper stands surrounding 84 Mesa.

The number of mule deer observed during the large mammal surveys for RBOSP is presented in Tables 3.30 and 3.31. The first table presents data by census area gathered during the 1974-1975 winter and the second table presents data accumulated after the modification of census area boundaries in June 1975, as described in the methods section of the Second Annual Report (RBOSP 1976).

A continuous change in mule deer density and distribution (Figures 3.26 - 3.31 in RBOSP Progress Report 10 1977) occurs throughout the winter in the study area. Density and distribution changes may be gradual or rapid and appear to be related to weather and snow accumulation patterns. A heavy snowfall in short period of time may cause a rapid change as observations during December 1974 seem to indicate. Observations during an extensive aerial survey by helicopter on December 27, 1974 for sex and age classification counts indicated a low density in the Dead Horse Ridge to Corral

TABLE 3.30

MULE DEER OBSERVED ON FOUR CENSUS AREAS DURING ELEVEN SURVEY PERIODS, WINTER, 1974-1975 for RBOSP 1/

Date of Census	Total Observed	Tract C-a	East	West	North of Tract 2/
November 8, 1974	33	14/35 3/	7/5	12/35	--
November 21, 1974	3	0/-	1/1	2/6	--
December 9, 1974	179	12/30	103/73	64/189	--
December 30, 1974	295	60/150	105/74	130/384	--
January 14, 1975	111	33/83	62/44	16/47	--
February 1, 1975	125	24/60	95/67	2/6	4/23
February 12, 1975	119	30/75	75/53	0/-	14/81
March 4, 1975	244	7/18	229/161	0/-	8/46
March 13, 1975	324	14/35	296/208	0/-	14/81
April 3, 1975	258	24/60	220/155	4/12	10/58
April 14, 1975	500	12/30	469/330	0/-	19/110

1/ The figures represent only those animals observed within the census area boundaries.

2/ Censuses on this area commenced during February, 1975.

3/ Actual number of animals observed/Extrapolated figure for number of animals observed per hour of observation.

TABLE 3.31

MULE DEER OBSERVED DURING 16 SURVEY FLIGHTS
JUNE 1975 TO SEPTEMBER 1976 FOR RBOSP.

		Mule Deer Observed		
Date of Census	Total	Transects East of Tract C-a	Transects for Tract C-a and Land to the North and South	Transects West of Tract C-a
June 26, 1975	0	0/- 1/	0/-	0/-
August 18, 1975	0	0/-	0/-	0/-
November 6, 1975	32	22/14	4/10	6/10
November 24, 1975	133	54/35	8/20	71/118
December 4, 1975	88	40/26	6/15	42/70
December 18, 1975	367	214/140	11/28	142/237
January 5, 1976	170	117/76	9/23	44/73
January 29, 1976	184	143/93	41/103	0/-
February 23, 1976	287	284/185	3/8	0/-
March 8, 1976	215	215/140	0/-	0/-
March 17, 1976	184	172/112	12/30	0/-
March 29, 1976	609	554/361	55/138	0/-
April 8, 1976	786	753/491	28/70	5/8
April 25, 1976	452	368/240	36/90	48/80
June 10, 1976	2	0/-	0/-	2/3
August 9, 1976	3	0/-	1/3	2/3

1/ Actual number of animals observed/Extrapolated figure for number of animals observed.

Gulch area west of Tract C-a, but observations during an aerial survey in a fixed-wing aircraft three days later indicated relatively large numbers of deer in the same area. A heavy snow had fallen between the survey dates and probably caused the rapid change.

As winter progressed and mule deer moved to lower elevations, they occurred in different habitats due to the change in vegetation types in conjunction with the elevational changes. In November, mule deer were generally distributed throughout the mixed brush and sagebrush types common in the western portion of the study area. By December, the higher elevations southwest of Tract C-a were not available for use due to snow depths; mule deer were scattered throughout most of the remaining portions of the study area, with the exception of an area north of Tract C-a and flat sagebrush-covered areas between Yellow Creek and Ryan Gulch. Only a few deer remained in the mixed brush-dominated area northwest of Tract C-a during January, while most of the deer were scattered throughout the pinyon-juniper and sagebrush types of Tract C-a and east of Tract C-a. Few deer were in the areas west of Tract C-a during February, and the density of animals in the pinyon-juniper and sagebrush types near Yellow Creek was relatively high. During March the deer appeared to be using the sagebrush vegetation type more heavily than in previous months. Few deer were on Tract C-a at this time; no deer were observed west of Tract C-a. By April the deer had started to move back into mixed brush areas west of Tract C-a, but the highest density was in and near bottomland meadows located in Yellow Creek and Ryan Gulch.

Observations during the aerial surveys indicate that vegetation type preferences occurred at various times during the winter. Most animals were in the mixed brush types during early winter, but as heavy snow rendered these areas unsuitable, the animals were more often observed in the sagebrush and pinyon-juniper vegetation types.

It appears that relatively more pellet groups occurred on northwest-facing slopes and less occurred on south-facing slopes during the winter periods than might have been expected based on sampling plot distribution (Figure 3.5).

Pinyon-juniper stands on north-facing slopes were used quite heavily according to winter tract studies in February 1975 and 1976 (RBOSP 1976). This may be due to deer preference for more favorable foraging conditions on the moist northwesterly-facing slopes compared to the drier south-facing slopes in the vicinity of Tract C-a. Most of the winter pellet groups were on slopes of 0 to 10° grade with fewer and fewer groups on the progressively steeper slopes (Figure 3.6).

Mule deer apparently do not concentrate in winter until deep snow forces them into the more limited areas of lesser snow depth. Some animals stay in the higher elevations where forage is more abundant as long as possible, then move to areas where their movements are not hindered by deep snow. These areas are usually south-facing slopes at the higher elevations as well as north-facing and other slopes at the lower elevations. Deer use thick brush or pinyon-juniper stands as cover from cold winds, but on still, cloudless winter days have been observed bedded in direct sunlight in the more open areas.

Mule deer appeared to range higher and were concentrated for a shorter period of time during the 1975-1976 winter than during the 1974-1975 winter. The 1975-1976 winter appeared to be milder and of shorter duration than the previous winter. CDOW reports also indicated that the 1975-1976 winter was quite mild, that deer distribution was scattered, and animals were found at the higher elevations on the far western and eastern end of the Piceance basin when winter counts were conducted (Bartmann 1976). The number of mule deer wintering on Tract C-a, the duration of their stay, and the habitats they occupy probably varies each year. In such a case as this, where the study area boundaries do not encompass the range of the animals, the differences observed in number, distribution, and amount of use probably are dependent more on annual varied weather conditions than on actual population density changes. The continual change in mule deer distribution and relative density on Tract C-a throughout the winter period, as indicated by results of winter aerial surveys, renders meaningless an overall winter density estimate for population parameter calculations based on a head count at any one particular time during the winter. An index of use throughout the entire period such as that provided by the pellet group counts would be more useful.

The pellet group index (pellet groups per acre divided by the accumulation period) is provided as an indication of population trends. Pellet group density estimates can be used directly as indications of population trends between areas or between years without consideration of defection rate, assuming rates are similar in all years (Neff 1968). For purposes of this discussion we assume that the unknown defecation rate will remain constant between areas and between years.

Deer appear to use the eastern portion of Tract C-a more than the western sections during the winter periods. Pellet group counts conducted during the 1974-1975 winter yielded indices of 0.33 and 0.58 for transects in the western portion of Tract C-a while indices of 1.16 and 0.92 were recorded for transects in the central and eastern portions of the tract. Results of pellet group counts on Tract C-a for the 1975-1976 winter indicate similar overall total use as well as area use patterns, although the difference between the various portions of the tract was not as great (Figure 3.3). The highest pellet group indices for the 1975-1976 winter were calculated for the central eastern portions of Tract C-a.

Mule deer rely mainly on browse for forage during the winter, but their diets are quite variable throughout the Rocky Mountain Area (Kufeld et al. 1973). Hansen and Dearden (1975) studied the diets of mule deer under stress in the Piceance basin and found that pinyon pine (*Pinus edulis*), Utah juniper (*Juniperus osteosperma*), big sagebrush (*Artemisia tridentata*), Utah service-berry (*Amelanchier utahensis*), and antelope bitterbrush (*Purshia tridentata*) together made up 96-98 percent of the forage consumed. Pinyon and juniper comprised about four-fifths of the mule deer foods but reasons for this high percentage are open to conjecture. The authors suggest that there may be a relationship between extremely cold winter temperatures and high percentages of pinyon and juniper.

Mule deer occurring in the study area are managed within the Piceance basin herd in Game Management Unit 22 by the CDOW. Results of sex ratio, age class, and mortality investigations on an area-wide basis can be more effectively used to estimate productivity of the population and aid management of the

deer than can similar data from a limited area exhibiting variable densities throughout the winter. These investigations plus distribution studies conducted throughout the Piceance basin also aid evaluation of the mule deer situation in the study area.

Game management Unit 22 has been listed among the top ten (rank range from 1st to 9th) units in the state for the highest number of hunters and largest number of deer harvested for several years (Colorado Division of Game, Fish and Parks 1971, 1972; CDOW 1973, 1974, 1975, 1976). The CDOW is presently attempting to manage the population so a large number of deer are available for harvest each year. The CDOW estimated a harvest of 1,982 deer by 4,617 hunters during the 1974 rifle season and 2,191 deer by 4,347 hunters during the 1975 season on the 1,033 square miles within the Unit (CDOW 1975, 1976). Hunters are not evenly distributed within the unit so the percentage of these figures attributable to Tract C-a and the surrounding area cannot be calculated, even though the area extent of Tract C-a has been computed. Based on the number of hunters observed during the 1975 and 1976 deer season, the study area receives heavy use from non-resident (outside State of Colorado) as well as resident hunters. The importance of the area is exemplified by the hunting club located in Section 33 on Tract C-a.

Over 40 percent of the deer wintering in the Piceance basin died during or immediately following the 1972-1973 winter (Bartmann 1974a, 1975b). The herd appears to be recovering and has shown an increase during the last surveys. The 1974-1975 winter deer count conducted by CDOW personnel indicated a projected population of 18,886 $\pm$ 3,458 (27.4/sq mi) at the 90 percent confidence level (Bartmann 1975a). The 1975-1976 winter count yielded 36.4 deer per square mile for a population estimate of 24,206 $\pm$ 3,724 deer at the 90 percent confidence level (Bartmann 1976). Post-season classification counts conducted throughout the Piceance basin in mid-December 1974 indicated a buck:doe:fawn ratio of 18:100:85 (Bartmann 1975a). Sex and age classification counts in the vicinity of Tract C-a conducted for RBOSP in late December 1974 indicated a buck:doe:fawn ratio of 18:100:92. The post-season survey conducted by CDOW personnel in 1975 yielded a ratio of 16:100:80, wich is two bucks and five fawns per 100 does fewer than in the CDOW counts of 1974 (Bartmann 1976).

The mule deer are not evenly distributed throughout the Piceance basin; the CDOW is presently conducting studies to delineate deer sub-population boundaries and concentration areas on the Piceance winter range (Bartmann 1975c). Tract C-a is located above the average upper winter range limit line for the Yellow Creek area as given by Baker (1970). The location of the line in the vicinity of the study area is given as follows: "The winter zone line south of Duck Creek includes most of 84 and Bar D Mesas, with necks that project southwestward up Corral Gulch and Stake Springs above the old 84 Ranch headquarters.

Excluded in this vicinity, however, is nearly all of Wolf Ridge between Corral Gulch and State Springs Draw. The winter line joins Ryan Gulch about one-half mile west of the old Ryan School. Elevations of the line between Duck Creek and Ryan Gulch vary within the range of 6,500 to 7,500 feet (Baker 1970; 13-14). The deer density of the western portion of the basin is generally considered to be lighter than in the central and eastern portions during most winters (Bartmann 1974b, 1976). Baker and McKean (1971) indicate that the entire area of Unit 22 can be used as summer range.

Based on the mule deer distribution patterns observed during the two winters of study, combined with the CDOW information summarized above, Tract C-a could be termed transition and upper winter range. During mild winters, Tract C-a and nearby areas will be used more extensively than during severe winters. Mule deer also use the area as they move between summer and winter ranges.

B. Elk

A relatively small number of elk occur in the RBOSP study area throughout the year. It appears that 15 to 20 elk ranged in and out of the study area throughout this period. Elk were generally located in mixed brush, aspen or Douglas-fir west of Tract C-a, but they have also been observed in pinyon-juniper types north, and sagebrush types south, of Tract C-a during spring mule deer migration movements surveys. Most elk sighted during summer activities were

southwest of Tract C-a. Elk tracks have been observed at the spring in Stake Springs Draw south of Tract C-a during spring and summer. Elk or recent elk sign were not observed on Tract C-a or east of the tract during the study.

Baker and McKean (1971) indicated that elk numbers within Unit 22 were low and those animals wintering in the Cathedral Bluffs-Calamity Ridge area on the western edge of the unit (near Tract C-a) probably summered in the south along the crest of the Roan Plateau. The winter populations in the unit appear to be greater than summer populations, probably due to movements into the unit from surrounding areas. The number of elk in Unit 22 has probably increased since Baker and McKean's report. They give total elk harvests of 17, 4, 21, 8, and 20, respectively, for the years 1965-1969. Big game elk harvest statistics for 1971-1975 are 12, 0, 67, 209, and 175 respectively (Colorado Division of Game, Fish, and Parks 1972; CDOW 1973, 1974, 1975, 1976). The statistics indicate a large increase in harvest since 1974. The number of hunters also increased considerably since 1973.

Elk diets generally contain a relatively lower percentage of shrubs (browse) and greater percentage of grass than mule deer diets. Kufeld (1973) reviewed food habit studies of Rocky Mountain elk throughout the western United States and Canada, and Boyd (1970) conducted food habit studies on elk of the White River Plateau in Colorado. These two papers were used for the following summary of elk food habits. Winter use is concentrated on either grass or shrubs depending on forage availability. Browse of all types represented 57 percent of the plants consumed from December through April in the White River study. Browse species used were oakbrush, aspen, serviceberry, big sagebrush, and snowberry. Most of the other forage consumed during winter were grasses.

Spring, summer, and fall diets are comprised primarily of grasses with relatively smaller amounts of forbs and browse. Grass averaged 78 percent of the diet over the summer months and 92 percent of the diet from September through November in the Colorado study. Forbs were taken mainly during mid-summer and late fall. Overall, the one-year study in Colorado reported 65 percent grass, 27 percent woody species, and 8 percent forbs on a frequency-of-occurrence basis for the summer samples.

Elk are not hampered by snow as much as are deer so they can remain at higher elevations west of Tract C-a during the winter. Since snow covers most of the grasses in this area during mid-winter, elk are forced to rely on browse to meet forage requirements. Elk occurring in the study area during summer share water sources with mule deer, wild horses, and domestic livestock. The elk also range freely between the study area and surrounding country to the north and south.

Other species of animals classed as big game have not been observed on the RBOSP study area during the two-year program. Observations of bighorn sheep (Ovis canadensis) have infrequently been reported in the Cathedral Bluffs area by deer hunters (personal communication, R. Krager, CDOW, Meeker 1975). They have not been substantiated but it is possible that bighorns occasionally wander through the area. Baker and McKean (1971) do not list bighorn sheep in species lists of Game Management Unit 22. Black bear (Ursus americanus) and mountain lion (Felis concolor) are addressed in the Mammalian Predators section which follows this Large Mammals section.

C. Wild Horses

Numerous bands of wild horses range over the study area. In contrast to the variable seasonal distribution of mule deer, wild horses are present throughout the year. The highest number of horses recorded during aerial surveys was 115 individuals on April 25, 1976 (Table 3.66 in RBOSP Progress Report 10 1977). This should not be considered as the total population in the study area, however. A herd of at least 16 animals on Dead Horse Ridge north of Tract C-a and bachelor studs scattered throughout the area were not observed on that survey. Based on aerial census and other field data, it is estimated that the area supports a minimum of 135 head of wild horses. BLM personnel estimated that 148 horses occupied the Square S and Box Elder grazing allotments (major portions of which encompass the study area) during the summer of 1975 (personal communication, B. Lawhorn, BLM, Meeker 1976).

Wild horse herds ranged in all vegetation types and various bands were scattered over a large portion of the study area during the two-year study

period (Figures 3.36 and 3.37 in RBOSP Progress Report 10 1977). Most of the horses were located in the area bounded by Big Duck Creek, Yellow Creek, Stake Springs Draw (up Left Fork Stake Springs Draw), and the Cathedral Bluffs, although scattered individuals or small bands were occasionally observed outside this area. Long range seasonal movements by the various herds were probably limited by barbwire fences. An attempt to delineate the ranges of specific bands, by noting color and distinguishing field marks of individuals within the band, was not successful. Variation in number of horses and color characteristics, recorded during repetitive observations of the herds, and general lack of obvious distinguishing marks, which would have allowed recognition of more individuals, did not permit monitoring the movements of identifiable units in most instances. Some interchange of individuals among the bands may occur. However, it is also likely that various individuals were screened from view during recurring observations which may have precluded consistent recording of band size and color combinations.

In addition to the horses associated with major herds in the study area, several solitary animals have been observed within the study area. These horses were generally assumed to be bachelor studs, either too young or too old to acquire and defend a herd of mares. The young stud near the Hunting Club, a bay stud south of Box Elder Gulch, a black stud observed near the road on 84 Mesa, and a roan stud north of KU Gulch appeared to be loners at the times when they were observed.

Feral horses demonstrated great mobility and during most seasons could easily travel over the study area until encountering fences. While deer and elk easily jump most fences, horse movements appear to be restricted by fences. Horses probably wouldn't cross a fence unless it was down or they were forced due to harassment. Consequently, most of the various vegetation and habitat types within the areas previously described exhibited evidence of horse activity. During the winter, many of the horses would forage along Cathedral Bluffs or on windswept ridge tops where forage was not covered by snow. The animals were located on these areas mainly during relatively good weather conditions and moved to dense brush, ravines, or the lees side of ridges during inclement weather. The wild horses occupying 84 Mesa and those remaining at the lower elevations in and near Tract C-a would seek shelter in pinyon-juniper

stands or gullies and would forage in the mixed brush and sagebrush vegetation types in these areas. The animals would paw forage covered by snow. Their size and strength permitted them to maneuver through all but the deepest drifts. Horses probably obtained sufficient water during the winter by eating snow.

During the summer, horses foraged in mixed brush, sagebrush, bottomland meadow, and bald vegetation types. They would loaf during mid-day near the same areas, often in an ecotone between two vegetation types or near large solitary trees. Many animals appeared to seek shade in pinyon-juniper stands during the hottest period of the summer day. Horses watered at springs or intermittent open water along Stake Springs, Box Elder Gulch, Corral Gulch, and Big Duck Creek. Depending on open gates or downed fences, horses on 84 Mesa could also water at Yellow Creek or stock tanks in Duck Creek. Horses are able to effectively graze areas many more miles from water than can domestic cattle, sheep, or most wildlife species (USDI 1973). Horses were also observed loafing in the bottomlands near water sources in Spruce Gulch during summer periods. At times, both wild and domestic horses lie down and roll over on their backs, possibly to scratch otherwise inaccessible parts of their bodies. Places where horses had rolled in the dust were evident at intermittent intervals on many of the roadbeds throughout the area.

Hubbard and Hansen (1976) report the principal year-round foods of wild horses in the Piceance basin were sedges (Carex spp), needle and thread (Stipa comata), wheatgrass (Agropyron spp), prairie junegrass (Koeleria cristata), bromes (Bromus spp), Indian ricegrass (Oryzopsis hymenoides), bluegrass (Poa spp), and common winterfat (Eurotia lanata), for mountain shrub, ecotone, and pinyon-juniper vegetation zones. Utah serviceberry (Amelanchier utahensis) was a principal food of wild horses in the mountain shrub zone. Horses probably browse the serviceberry most during winter when grasses are covered by snow in all but the windswept areas. In contrast to the seasonal consumption of forage by mule deer and cattle, horses consume forage during all seasons and therefore have the potential to affect range resource at all times during the year.

New-born foals begin appearing in many of the herds by mid-April. The peak foaling period is May (personal communication, B. Lawhorn, BLM, Meeker 1976).

A few foals are born throughout the summer and relatively young foals have been observed as late as September, but these probably have little chance to survive the harsh winter conditions. Foals represented approximately 20 percent of the horses observed during the period late May through December 1975. Age classes recorded during individual aerial surveys conducted from June through December 1975 varied widely, but, overall, foals accounted for approximately 15 percent of the animals that had been positively classified during the period. Approximately 20 percent of the 136 horses classified by the BLM personnel during summer 1975 were foals (personal communication, B. Lawhorn, BLM, Meeker 1976). There appeared to be a higher percentage of foals in the population during summer 1976. Foals represented approximately 24 percent of the horses observed during summer 1976 and accounted for 18 percent of the horses classified during the mid-summer aerial survey, representing an increase from the previous year's results.

Dead horses and skeletons have been observed on the study area. However, the cause of the mortality was generally not evident. Foals probably suffer high mortality during winter when forage is covered by snow and they must compete with stronger adult horses for food (personal communication, B. Lawhorn, BLM, Meeker 1976). Deep snows may even trap adult animals, causing starvation. Predators probably have limited influence on horse mortality. Prior to the wild Free-Roaming Horses and Burro Act of 1971 horses were trapped or rounded up and sold.

D. Large Mammal Interrelationships

An ecosystem such as the study area has so many actions and reactions occurring that certainly all have not been observed, much less studied, to the extent where the interrelationships are clearly defined. Some interactions of the large mammals with each other, smaller animal species, and the range resources can be inferred from observations during field activities. However, only the most obvious activities and interrelationships will probably be noted.

Competition for forage is one obvious important potential interaction of the large herbivorous mammal species. Cattle are mainly grazers, eating grass and forbs. However, they will occasionally browse shrubs throughout the summer and will consume large amounts of browse in late fall. Mule deer consume mainly browse plant species, but at certain times, such as spring, graze on the initial grass growth and forbs. Elk seem to prefer grass and forbs throughout the year, but consume browse during the winter. Wild horses rely mainly on grass but browse serviceberry at the higher elevations (Hubbard and Hansen 1976). Competition for food occurs to the extent that the various species consume the same forage on the range. On the other hand, a complementary food relationship would exist when the various herbivores consume different forage species, provided that the total consumed by all species was not excessive to the point of range deterioration. Cattle consumption of grass can reduce competition for moisture and nutrients in favor of browse plants used by mule deer.

Hubbard and Hansen (1976), reporting high dietary overlaps between wild horses and cattle, suggest that competitive food relationships could develop if stocking rates of horses and cattle are not balanced with production of sedges and grasses in the Piceance basin. Although wild horses and mule deer consumed high percentages of Utah serviceberry in the mountain shrub zone, the diets of mule deer were generally quite different from the wild horses and cattle, suggesting complementary rather than competitive potential food relationships. McKean and Bartmann (1971) indicate that cattle and mule deer on pinyon-juniper range can be grazed in combinations if kept at moderate rates (2 acres per deer per month and 20 acres per cow per month) without serious competition and range regression. Elk diets overlap with the diets of mule deer, wild horses, and cattle. Since elk can winter at higher elevations, they are able to browse food unavailable to mule deer during part of the winter. However, the deer have already consumed part of the browse in their migration through the area. The small number of elk present in the study area limits the extent of their interaction with other species. Overstocking of any one large mammal species would cause increased competition for forage, not only with other species occurring on the same area, but between individuals of the overstocked species as well.

Interactions other than those dealing with forage also occur between the large mammals. Horses traveling and pawing through snow for their own food may uncover forage for deer. They may also open trails through deep snow to areas which otherwise would be inaccessible to mule deer. Competition for water, between individuals of any one species as well as between the various species, may occur during the summer. This competition probably only occurs if the animals use the same water source at the same time. Protective cover suitable for use during the winter is another potential competition area in severe cases, where food sources may be depleted near good cover.

In addition to the large mammal species interrelationships with each other, they also interact directly and indirectly with other animals. Herbivorous animals such as sage grouse, chipmunks, and phytophagous insects can have either competitive or complementary interrelationships with the large mammals, depending on foods they eat, in a similar manner to the interactions between large mammal species. Oakbrush resprouts, which are deer and elk winter forage, may be stimulated after porcupines have killed the mature plant by eating the bark during the previous winter. Insect pests such as mosquitos and bot flies cause undesirable conditions for large mammals. Other insect activities, such as plant pollination or predation of undesirable insect species, benefit the large mammals. Insectivorous birds and mammals benefit the large mammals by reducing undesirable insect pests, but they also reduce the number of beneficial insects. Large mammals provide food sources for coyotes and other predator/scavenger animals such as ravens, magpies, and golden eagles. Coyotes have been observed preying on mule deer, the carcasses of which also provide food and shelter for various insects.

Large herbivores and the forage resources in the Tract C-a vicinity also interact in various ways. Many factors influence the condition and trend of the range, including the grazing pressure exerted by wild and domestic herbivores. Range condition and trend studies indicate that most of the study area is in fair condition with almost half of the area exhibiting upward trend. The pinyon-juniper vegetation type contributed the largest proportion of poor condition and downward trend classifications. Pinyon-juniper sites were also the lowest producing ranges sampled in the range production-utilization studies. Pinyon-

juniper may be in poor and deteriorating condition, due, in part, to heavy use of this type by large mammals throughout the year. Mule deer and horses use it as shelter during severe winter weather when large groups of animals must rely on only a small portion of total range. Cattle use the type during spring and fall, and some of the horses occur in the type the entire year. An increase in the stocking rate would likely halt the general upward trend, thereby preventing the range from achieving a good condition class. If favorable growing conditions, combined with the present stocking rate, occur for the next few years, it is expected that the upward trend will continue. Browse was almost entirely in the excellent condition class. However, a large portion exhibited a downward trend. Mule deer distributional variation throughout the winter allows more even use of the browse over all the range.

Browsing by animals often stimulates growth of plants such as serviceberry, oakbrush, mountain mahogany, and bitterbrush. Severe browsing, such as has been observed in various plants on the lower elevations of the study area, may retard plant growth. Browse plants on lower elevations have assumed growth forms characteristic of plants under moderate to heavy utilization, while the same species of plants at the higher elevations generally exhibit little or no hedging. Some shrubs on the higher elevations have grown to the extent that most production is unavailable to deer, while plants on the lower elevations have been browsed down sufficiently each year to keep most of the new growth within reach of mule deer. Seeds of various plants may be distributed by animals when they are ingested, then deposited elsewhere in feces.

III. MAMMALIAN PREDATORS

The purposes of mammalian predator investigations were to document the presence, distribution, and relative abundance of large and small mammalian predators within the study area. An additional objective was to determine, through examination of existing information, the impact these predators may have on big game, domestic livestock, and other ecosystem components.

Results of the scent-station visitation technique, winter tract counts, opportunistic observations (including those of tracks, scats, and other definitive signs), and limited predator live-trapping indicate that the coyote and long-tailed weasel are the two most abundant mammalian predators in the study area. These were the only species represented in the scent-station survey. Four other carnivorous mammals were documented on and near Tract C-a: the ermine, captured during the live-trapping program; the bobcat, for which tracks were observed during winter track counts and a skull and scat found during other field sampling; the badger, observed in the upland sagebrush vegetation type, with burrowing evident throughout the study area; and the skunk (probably the striped skunk), for which tracks were observed near refuse bins at a local hunting camp. The mountain lion, black bear, pine marten, grey fox, and ringtail are known to reside in the region; however, evidence of these animals was not noted in the study area. Other mammalian predators occurring in western Colorado, such as the raccoon, mink, and red fox, prefer riparian or agricultural vegetation types but may utilize the habitats found on Tract C-a infrequently.

Coyote populations appear to be about average for the region. The results of the scent station survey and the corresponding relative abundance indices for all sampling periods are summarized in Table 3.32 and the results of comparable federally-surveyed lines set within areas of similar habitat and physiography (USDI 1973, 1974, 1975) are presented in Table 3.33.

TABLE 3.32

SCENT-STATION VISITATION TECHNIQUE RESULTS AND RELATIVE ABUNDANCE INDICES[1/]
AS CALCULATED FROM DATA COLLECTED ON AND NEAR TRACT C-a (1974-1976) FOR RBOSP.

Sampling date	Oper. Stat. Nights	Coyote Index/No. of visits	Weasel Index/ No. of visits
November A[2/] 1974	211	19/4	14/3
February A 1975	166	78/13	12/2
June A 1975	228	26/6	26/6
June B 1975	172	35/6	35/6
October A 1975	187	37/7	27/5
October B 1975	193	47/9	26/5
February A 1976	148	47/7	27/4
February B 1976	161	19/3	0/0
June A 1976	205	29/6	15/3
June B 1976	194	26/5	10/2

1/ Relative abundance index = $\left[\frac{\text{Number of visits by species}}{\text{Number of operable station nights}}\right] \times 1000$

2/ Scent-station line A, the northern line (see map in second annual report for location of scent-station sampling lines). Line B was not established until June, 1975.

TABLE 3.33

SCENT-STATION VISITATION TECHNIQUE RESULTS AND RELATIVE ABUNDANCE INDICES FROM FEDERALLY-SURVEYED LINES WITHIN GENERALLY SIMILAR HABITATS WITH SIMILAR PHYSIOGRAPHIC CHARACTERISTICS (1973-1975) AS THOSE SAMPLED FROM RBOSP.

Colorado

	1973			1974			1975		
Survey line number	14	17	18	14	17	18	14	17	18
Operable station nights	250	250	250	248	191	239	250	224	219
Coyote index	148	96	28	48	26	54	72	22	27
Number of visits	37	24	7	12	5	13	18	5	6

Utah

	1973			1974			1975		
Survey line number	5	6	7	5	6	7	5	6	7
Operable station nights	200	199	250	140	192	250	230	250	200
Coyote index	60	45	20	7	26	164	26	44	60
Number of visits	12	9	5	1	5	41	6	11	12

Gier (1957) calculated a spring breeding population density of 0.27 coyotes/ km^2 (0.7/sq mi) in six counties of Kansas. French et al. (1965) reported 0.12 coyotes/km^2 (0.3 sq mi) after the breeding season in southeastern Idaho. Coyote population densities in northern Utah were astimated to be 0.10, 0.10, 0.09, 0.11, and 9.14 coyotes/km^2 (0.26, 0.26, 0.23, 0.29, and 0.37 coyotes/sq mi each year from 1966 to 1970, respectively (Clark 1972; Wagner and Stoddart 1972). Knowlton (1972 suggested that population densities of 0.2 - 0.4 coyotes/km^2 (0.5 - 1.0 sq mi) seem realistic for coyotes over much of their range. His study, however, was performed in Texas where coyote densities are known to be high. Relative abundance indices are characteristically higher on the plains than in the mountains, and population densities presented for southeastern Idaho and northern Utah are probably more representative of coyote densities in the Tract C-a study area (i.e., 9.1 - 0.2 coyotes/km^2). Results of the siren-elicited howling response (Table 3.34) generally support this concept.

Population indices derived from studies performed on neighboring Tract C-b are generally much higher than those for C-a (C-b Shale Oil Project 1976). However, scent station lines used for the C-b study were placed in locations suspected of being good coyote habitat and therefore, strict comparisons may not be justifiable. Indices of relative abundance for Tracts U-a and U-b (VTN Colorado, Inc. 1976) are much lower than those obtained on Tract C-a. This is probably a result of the high level of predator control practiced in the U-a - U-b area because it is used heavily for sheep grazing. Predator control would not only tend to reduce the coyote population, but would also tend to reduce the response of the remaining animals to the scent-station technique.

Coyotes are active year-round in the Tract C-a study area in all habitat types. Sampling on Tract C-a revealed no seasonal coyote activity patterns; however, researchers on Tract C-b noted that the highest coyote density on that study area shifts to lower elevations during mid-winter and early spring, when deer carrion from winter-kill provides an abundant food source (C-b Shale Oil Project 1976). A similar trend may occur on Tract C-a.

TABLE 3.34

COYOTE SIREN CENSUS RESULTS CALCULATED FROM DATA COLLECTED DURING 1974-1976 FOR RBOSP

Sample Period	No. of Stations Sampled	No. of Responses	No. of Groups	Station Resp. Index 1/	Group Resp. Index 2/
November 1974	15	10	13	67	87
February 1975	11	7	10	64	91
June 1975	20	10	20	50	100
October 1975	10	4	4	40	40
February 1976	15	8	11	53	73
June 1976	20	11	19	55	95

1/ Station Response Index $= \left[\frac{\text{Total number of stations with response}}{\text{Total number of stations}}\right] \times 100$

2/ Group Response Index $= \left[\frac{\text{Total number of groups responding}}{\text{Total number of stations}}\right] \times 100$

Coyotes are primarily nocturnal although they may be active at any time of the day. They consume a variety of plants and animals taking generally whatever is available. Most information on their food habits suggests that rodents and rabbits are the main items of diet; but they may depend on fruits or carrion, and under some circumstances, may even kill and consume big game animals (Lechleitner 1969). Seasonal rodent abundance probably plays an important part in Coyote dietary habits in the study area. Lagomorph censuses indicate that rabbits are presently not abundant, but populations are increasing slowly. Therefore, increased predatory pressure may be placed on rodents at this time. Winter track count data from a bottomland meadow habitat indicate that small mammal abundance and the relative ease with which mice and voles may be captured in that habitat type have attracted coyotes to hunt the meadow extensively. Although dietary information for the coyote has not been systematically gathered in the study area it can be assumed that when rodents, such as ground squirrels and chipmunks, become abundant during the warm months they are preyed upon extensively by the coyotes. Serviceberry and juniper berries are probably also important during summer; evidence of these fruits was noted in several coyote scats found on Tract C-a. During the winter period when many rodents are inactive and fruits are unavailable, coyotes probably resort to more intensive hunting of lagomorphs and winter-active mice and voles and feed heavily on carrion. During harsh winter conditions they may prey upon mule deer. During the winter of 1974, three adult coyotes were observed attacking and killing a mature mule deer doe immediately west of Tract C-a boundaries in Corral Gulch.

Rasmussen (1941) examined coyote scat collected during mid-winter from a pinyon-juniper ecosystem in northern Arizona. He found scat consisting mainly of deer hair and bones, some rabbit fur, and the remains of deer mice. He found both mule deer carrion that had been fed upon by coyotes and fresh mule deer that had been killed and eaten by coyotes. Coyote scat collected from the same area during summer consisted primarily of rodents, serviceberries, juniper berries, prickly pears, and grass (Rasmussen 1941).

Interviews with area cattle ranchers indicate no problem with domestic livestock depredation by the coyote. Sheep do not graze in the area.

Weasels were observed in all vegetation types but activity was most commonly noted in vegetation types having the densest shrub cover (i.e., sagebrush, rabbitbrush, and mixed brush). Weasels prey heavily on small mammals, characteristically consuming three to four per day (Quicks 1951). Small mammals were also found to occur in highest densities in vegetation types with high shrub cover, thus accounting for greater utilization of these types by weasels. The deer mouse, red-backed vole, and long-tailed vole are probably important prey species for the weasel, since all three are relatively abundant and active throughout the year. Chipmunks, primarily the least chipmunk, may be an important element of the weasel's diet during the warmer months when this prey species becomes common.

The long-tailed weasel has the broadest ecological and geographic range of any mustelid in Colorado. It is almost always numerically dominant to the smaller ermine or short-tailed weasel which is not believed to be common anywhere in Colorado (Armstrong 1972). Quicks (1951) found population densities of 0.8 long-tailed weasels/km^2 (2.0/sq mi) in Gunnison County, Colorado. Population densities on the study area may be somewhat lower than this figure because of sparser vegetation cover in the vicinity of Tract C-a.

A single badger was observed on Wolf Ridge late at night during February 1975. The burrowing activity of this species is evident in many places throughout the study area. Badgers feed primarily on small mammals such as the golden-mantled ground squirrel, northern pocket gopher, and least chipmunk, which they excavate from their burrows (Lechleitner 1969). For this reason, badgers prefer situations with loamy soil and probably use ridgetops and valley bottoms within the study area much more often than side slopes. Tract C-b studies indicate that a limited population of badgers occurs in that area (C-b Shale Oil Project 1976).

Bobcat sign was noted during winter track count studies and observed opportunistically during various other field activities; a bobcat skull was also found. This species occurs much less frequently on the study area than the coyote and was not represented in scent-station surveys, hence the formulation of relative abundance indices was not possible. Probably only a few individuals inhabit the

area. Bobcats prefer rough, broken terrain and are probably most common along the rimrock areas of Ryan Gulch, Duck Creek, and other drainages within the study area. Studies on Tracts U-a and U-b as well as on Tract C-b indicate similarly low population levels. Personnel of the Utah Division of Wildlife Resources attribute bobcat population reduction to heavy trapping because of extremely high fur prices, increased accessibility of remote areas, and the relative ease with which a bobcat may be trapped (VTN Colorado Inc. 1976).

Skunk tracks were observed near a refuse bin at a local hunting camp just south of Tract C-a. Closer investigation revealed that the skunk was residing under the cabin. Although absolute species identification is not possible from the track alone, it is believed that this individual was a striped skunk, which is known to take up residence in such locations (Lechleitner 1969). The skunk is probably a relatively rare resident of the tract environs because of its preference for agricultural or riparian habitats which are scarce within the study area.

There have been no verified reports of black bear or mountain lion on the study area. Local ranchers, however, have reported occasional sightings of both species along Cathedral Bluffs. It can be assumed that while these animals probably do not reside in the immediate Tract C-a area, they may utilize it occasionally.

The marten occurs throughout the Colorado mountains in areas of dense forests. Suitable habitat exists within the study area but patches of Douglas-fir are probably too isolated to support this species successfully. There have been no reports of this mammal in the Tract C-a area.

The ringtail is another possible predator of the study area. There has been no positive documentation of this species locally. Habitat is not ideal in the area, since the ringtail prefers high cliffs and rocky outcrops especially in conjunction with large trees. This secretive and nocturnal animal, however, is difficult to detect even in areas where it is common (Lechleitner 1969). Ringtail sightings have been recorded approximately 25 miles south of Tract C-a in the Parachute Creek drainage (ECI 1975). The grey fox may also be an occasional

resident but there is no verification of its occurrence in the study area either.

Other carnivorous mammals of western Colorado such as the red fox, raccoon, or mink prefer riparian or agricultural vegetation types of which there are very few in the study area. It is likely that individuals may occasionally travel upstream to various tract drainages from Piceance Creek. Studies on Tract C-b, which is much nearer to the creek, report that the raccoon occurs regularly in the area (C-b Shale Oil Project 1976).

IV AVIFAUNA

The avifauna data collection program was designed to identify the species of birds occurring in the vicinity of Tract C-a; to determine, where feasible, the factors regulating their distribution and abundance in the dominant habitats; and to aid in developing a designation of important species.

During nine census periods, 139 species have been observed within the study area (Table 3.13 in RBOSP Progress Report 10 1977). All functionally important components of the Tract C-a avifauna are included in this tabulation. Many unlisted species of minor transient importance undoubtedly appear in the tract vicinity from time to time during migration, so it is expected that the inventory of species utilizing habitats in the area will continue to expand. Certain of the species that might be sighted will be waterfowl and upland gamebirds having extremely limited recreational importance in the study area, and migratory songbird and raptor species having limited ecological importance, due to their scarcity on the study area.

Table 3.75 in RBOSP Progress Report 10 (1977) lists the 67 bird species expected to occur but not observed on Tract C-a. The species on this list were either observed by field researchers in other portions of the Piceance basin or Roan Creek basin or recorded by Bailey and Niedrach (1965) in Moffat and/or Rio Blanco counties.

Songbirds, gamebirds, waterfowl and shorebirds, and raptorial birds are discussed separately. Seasonal activity levels, population habitat distribution, population density, species diversity in different habitats, ecological interrelationships, migratory patterns and importance indices are discussed, where appropriate.

A. Songbirds

The discussion of bird communities within the 15 habitats sampled on the Tract C-a study area during the interval from October 1974 through June 1976 (RBOSP 1976) focuses on three parameters: relative abundance, species composition, and species diversity. Also, some factors affecting these parameters on a yearly and seasonal basis are discussed.

Songbird species observed on or close to Tract C-a during nine periods of field inventory from October 1974 through June 1976, and their status and habitat of observation are listed in Table 3.13 in RBOSP Progress Report 10 (1977); population density changes and species diversity changes in the 15 habitats sampled by strip transect (RBOSP 1976) are presented in Tables 3.35 and 3.36 and an interpretation of these data is discussed in RBOSP Progress Report 10 (1977). Results of the quantitative avian sampling program are presented in Appendix A of RBOSP Progress Report 10 (1977).

The two-year seasonal data for each habitat type were combined and coefficients of detectability were recalculated based on methods described in the RBOSP Terrestrial Annual Report (1976).

Key relationships between the avian community and other components of the Tract C-a ecosystems are identified through the important species of each community. "Important" species are emphasized herein, as a means of conveniently illustrating ecological dependencies of avian community components on Tract C-a and adjacent habitats.

The designation of important species, to some extent, reflects a human value judgement which is not easily quantified. According to Nuclear Regulatory Commission guidelines (1975), the importance of a species may be a function of its status as a rare or endangered species, its aesthetic qualities, its role in the energy or nutrient cycling processes of ecosystems, or its function in controlling the dynamics of other populations. In the case of songbirds, the relative abundance and frequency of occurrence of a species provide an index to its biological importance. Thus, any summation of the relative abundance and the relative frequency of a particular species provides an "importance value" for that species. Such a value could approach a maximum only if the species were frequently encountered and were in large numbers during each encounter. However, an intermediate value could be obtained either by encountering at least one individual of the species on most transects, or by encountering a large number of individuals of that species on one or a few transects.

An importance value was calculated from the density estimates for songbird

TABLE 3.35

AVIAN SPECIES DIVERSITY INDICES IN 15 HABITATS SAMPLED DURING 1974-1976 FOR RBOSP

Habitat	Sampling Period								
	10/74	12/74	2/75	4/75	6/75	10/75	2/76-3/76	4/76	6/76
Agriculture	0.54	0.67	1.32	1.33	2.69	1.19	0.22	1.27	1.99
Upland sagebrush	0.00	--2/	--	0.00	1.09	0.79	0.66	0.00	1.71
Rabbitbrush	1.50	--	.43	0.45	1.20	1.78	0.69	1.73	1.42
Pinyon-juniper/ mixed brush	0.35	--	--	--	1.63	1.48	1.76	1.89	2.33
Mixed brush	0.69	0.33	0.00	--	1.33	0.94	1.52	0.76	1.88
Pinyon-juniper/ sagebrush	0.29	0.00	--	--	2.18	1.36	1.57	1.93	2.67
Bald	1.06	*1/	--	0.00	1.54	0.00	*	1.18	1.32
Bottomland sagebrush	0.97	0.00	--	0.89	1.74	1.74	0.80	2.19	1.47
Pinyon-juniper	0.50	--	--	0.49	2.14	0.53	1.79	1.28	2.11
Pinyon-juniper	0.78	0.00	1.13	--	1.51	0.87	1.57	1.10	2.48
Upland sagebrush	--	*	--	--	1.20	1.23	0.00	1.76	1.27
Mixed brush	0.64	*	1.05	0.35	1.42	0.10	0.68	0.92	1.28
Douglas-fir	0.97	*	1.38	0.98	2.32	1.51	1.65	1.59	1.83
Aspen	1.04	*	0.22	1.34	2.34	0.91	*	0.58	2.15
Riparian	1.02	*	--	1.63	2.13	0.66	0.35	1.27	2.28

1/ Habitat not sampled.

2/ Insufficient observations to calculate.

TABLE 3.36

TOTAL AVIAN DENSITIES IN 15 HABITAT TYPES SAMPLED DURING 1974-1976 FOR RBOSP

Habitat	Sampling Period								
	10/74	12/74	2/75	4/75	6/75	10/75	2/76-3/76	4/76	6/76
Agriculture	2.51	0.26	0.82	1.16	6.72	1.18	2.62	3.43	10.29
Upland sagebrush	0.66	0.00	0.00	0.61	1.50	2.01	3.01	0.25	5.47
Rabbitbrush	6.90	0.00	1.74	0.74	2.50	8.62	0.20	2.09	7.23
Pinyon-juniper/ mixed brush	0.46	0.00	0.00	0.00	2.49	1.82	3.41	0.92	9.34
Mixed brush	.92	1.02	0.05	0.00	1.99	3.38	0.58	0.56	4.98
Pinyon-juniper sagebrush	13.16	0.41	0.00	0.00	4.30	4.59	0.42	7.43	8.71
Bald	2.05	*1/	0.00	0.15	2.24	4.71	*	1.38	2.12
Bottomland sagebrush	1.52	0.05	0.00	13.92	6.54	6.50	1.36	2.41	3.60
Pinyon-juniper	0.26	0.00	0.00	0.77	4.41	0.92	2.19	0.36	5.94
Pinyon-juniper	2.26	0.26	4.57	0.00	9.96	4.82	1.27	0.15	12.12
Upland sagebrush	0.00	*	0.00	0.00	5.18	5.54	0.20	2.03	4.39
Mixed brush	24.59	*	7.38	3.69	3.69	5.02	0.36	4.76	9.22
Douglas-fir	4.79	*	14.89	3.83	6.89	2.70	13.92	2.01	13.57
Aspen	3.56	*	0.87	6.26	9.40	2.38	*	3.78	6.37
Riparian	11.83	*	0.00	22.87	21.39	5.05	0.92	3.76	24.68

1/ Habitat not sampled.

species recorded during all seasons on the 15 transects sampled during the baseline program. These values permit ranking the relative importance of each species in each habitat during the breeding season and are shown in Table 3.70 of RBOSP Progress Report 10 (1977).

The importance value (IV) for each species in a given habitat is defined as follows:

IV = Percent Relative Frequency + Percent Relative Abundance where:

$$\text{Percent Relative Frequency} = \frac{\text{\# of censuses during which species A is encountered for all sample periods}}{\text{\# of census replications during all sample periods}} \times 100$$

$$\text{Percent Relative Abundance} = \frac{\text{\#/ha of species A during all sample periods}}{\text{\#/ha of all species during all sample periods}} \times 100$$

The two songbird species achieving the largest importance values over all sampling periods for each habitat type were considered the principal species for that habitat type. Table 3.37 indicates the important songbird species in each habitat type.

The key ecological interactions of each important species within its important habitat types are presented in Table 3.38 Within this table the status and occurrence, trophic relationships, breeding history and nesting requirements, and some other important interactions such as interspecific songbird competition, are presented. The interactions listed in this table are only repeated in the narrative where further emphasis on these interactions is deemed necessary. Additional interactions not noted in Table 3.38 are also discussed when pertinent. The results are discussed by seasons and species and habitat differences within seasons.

The greatest number of species encountered during the two fall sampling periods occurred within the rabbitbrush, bottomland sagebrush, and Douglas-fir vegetation types. Large flocks of birds observed in the mixed brush (upland), pinyon-juniper

TABLE 3.37

IMPORTANT SONGBIRD SPECIES IN EACH HABITAT TYPE (ALL SEASONS COMBINED)

SAMPLED DURING OCTOBER, 1974 THROUGH JUNE, 1976 FOR RBOSP

Species	Transects 1 Agriculture	2 Upland sagebrush	3 Rabbitbrush	4 Pinyon-juniper Mixed brush	5 Mixed brush	6 Pinyon-juniper sagebrush	7 Bald	8 Bottomland sagebrush	9 Pinyon-juniper	10 Pinyon-juniper	11 Upland sagebrush	12 Mixed brush	13 Douglas fir	14 Aspen	15 Riparian
Horned lark		X					X								
Scrubjay						X			X						
Black-capped chickadee													X	X	
Mountain chickadee										X			X	X	
Robin	X														
Mountain bluebird			X	X		X			X	X	X				
Red-winged blackbird	X														X
Green-tailed towhee					X										
Vesper sparrow							X				X				
Sage sparrow		X													
Dark-eyed junco				X	X			X				X			
Gray-headed junco								X				X			
Brewer's sparrow			X					X							
Song sparrow															X

TABLE 3.38

PRIMARY ECOLOGICAL INTERACTIONS OF IMPORTANT AVIAN SPECIES RECORDED ON THE TRACT C-a STUDY AREA DURING 1974-1976 FOR RBOSP 1/

Species	Important Habitats	Status and Occurrence	Predominant Food Items and Feeding Habits	Breeding History and Nesting Requirements	Common Predators	Other Important Interactions
Horned lark	1. Bald 2. Upland sagebrush	1. Common year-round resident in bald habitat; common fall and winter resident and uncommon breeding resident in upland sagebrush habitat	1. Ground feeder 2. Fall & winter-herbivorous; for upland grass seeds (e.g. Poa sp., Agropyron sp., Astragalus sp. 3. Spring & summer-omnivorous; forb and grass seeds; insects (beetle adults and larvae, grasshoppers, caterpillars)	1. Incubating eggs by early March; egg-laying dates dependent on weather; long winter may prolong egg-laying until April or May. Incubation period-10 days; 2-5 eggs laid 2. Nestling period - 11 days 3. Nest site-ground; prefers barren ground near bunch grass (Poa sp., Agropyron sp.) 4. Nest structure - grass cup w/courtyard paved w/small stones; placed in a depression in ground	1. Adults -Cooper's hawk, sharp-shinned hawk, short-eared owl, prairie falcon. 2. Eggs & young-Scrub jay, black-billed magpie, common raven, short-tailed weasel; golden-mantled ground squirrel, coyote	1. Nests early in spring due to abundance of previous year's seed crop & barren ground availability. If nested later many seeds would have germinated, limiting barren ground space and seed abundance 2. It's early nesting & preference for wind swept habitats limits the amount of nesting & winter competition w/other ground nesting & ground feeding songbirds
Scrub jay	1. Pinyon-juniper 2. Pinyon-juniper/sagebrush	1. Common year-round resident	1. Ground feeder 2. Omnivorous year-round; plant food predominant (pinyon pine seeds, juniper berries, serviceberry fruit); insects eaten predominantly during spring & summer (grasshoppers, wasps, & bees)	1. Incubating eggs by early May; 3-6 eggs laid 2. Nest site-placed in sagebrush, serviceberry, pinyon pines or junipers; prefers dense vegetation 3. Nest structure-coarse structures of dead shrub & tree twigs w/well-lined cups of rootlets	1. Adults-great horned owl, screech owl, Cooper's hawk, goshawk 2. Eggs & oung-Pinyon jay, common raven, thirteen-lined ground squirrel, coyote	1. Some competition w/pinyon jays & black-billed magpies for food 2. Its abundance is regulated by the number of omnivorous ground-feeding & foliage feeding species present
Black-capped chickadee	1. Douglas-fir 2. Aspen	1. Common year-round resident	1. Timber feeders 2. Predominantly insectivorous; plant material consumed during winter. Winter-moth eggs, plant lice, katydids, spiders, Douglas-fir seeds; choke cherry, snowberry, & serviceberry fruit 3. Spring, summer, fall-moths, caterpillars, spiders, beetles, leaf-hoppers & tree hoppers	1. Incubating eggs during April & May Incubation period-12-19 days; 6-9 eggs laid 2. Nestling period 16-20 days 3. Nest site-prefers nest cavities excavated in rotten stumps 5-6 feet above ground 4. Nest structure-small cup made of grass, hair & occasional feathers	1. Adults-goshawk, Cooper's hawk, great howned owl 2. Eggs & young-Stellar's jay, black-billed magpie	1. May avoid competition w/mountain chickadee for food during summer by maintaining slightly different diets 2. During winter inter-specific flocking w/mountain chickadees & ruby-crowned kinglets occurs. This probably aids in food-finding, protects against predators, & satisfies gregarious tendencies
Mountain chickadee	1. Pinyon-juniper 2. Douglas-fir 3. Aspen	1. Common year-round resident in Douglas-fir & pinyon-juniper; common breeding resident & migrant in aspen	1. Similar to black-capped chickadee. The two related species might concentrate on different food items to avoid competition in Douglas-fir & aspen. In pinyon-juniper woodland pinyon pine seeds are eaten during winter	1. Similar to black-capped chickadee	1. Similar to black-capped chickadee. In addition scrub jays & pinyon jays prey on eggs & young in pinyon-juniper woodlands	1. See black-capped chickadee 2. Chickadees aid in maintaining healthy forests by consuming tree parasites (pine bark beetles)
Robin	1. Agriculture	1. Common breeding resident & spring migrant	1. Ground feeder 2. Predominantly insectivorous-earthworms, caterpillars, ground beetles	1. Incubating eggs during late April & early May. Incubation period - 12-13 days; 3-4 eggs laid 2. Nestling period-13-16 days 3. Nest site-open nest amidst a variety of vegetation; preferred sites in grass & sagebrush 4. Nest structure - medium-sized cup of grass & mud	1. Adults-great horned owl, short-eared owl, prairie falcon 2. Eggs & young-scrub jay, black-billed magpie, golden-mantled ground squirrel, coyote	1. Tolerant nesting species - shares nest incubating & brooding w/such species as mourning dove & house finch 2. Severe weather in spring may be a significant mortality factor in robin populations 3. Some competition for food w/other ground feeders (mountain bluebird, mourning dove)

TABLE 3.38 (continued)

Species	Important Habitats	Status and Occurrence	Predominant Food Items and Feeding Habits	Breeding History and Nesting Requirements	Common Predators	Other Important Interactions
Mountain bluebird	1. Rabbitbrush 2. Pinyon-juniper/ mixed brush 3. Pinyon-juniper/ sagebrush 4. Pinyon-juniper 5. Upland sage-brush	1. Common breeding resident & migrant	1. Ground feeder 2. Predominantly insectivorous- ground beetles, weevils, grasshoppers, ants, caterpillars, crickets 3. Small amount of fruit (currant, serviceberry) is also consumed	1. Incubating eggs in early April. Incubation period - 14 days; 5-8 eggs laid 2. Nestling period - 17-18 days 3. Nest site - hole nester, (pinyon pines, junipers, fence posts, buildings) 4. Nest structure - grass & feathers	1. Adults - Cooper's hawk, sharp-shinned hawk, great horned owl, screech owl 2. Eggs & young - black-billed magpies, common raven, scrub jay, pinyon jay, short-tailed weasel, golden-mantled ground squirrel, coyote	1. Suffers from competition for cavity nest sites w/small owls, house wrens, tree swallow, deer mice & wasps. To avoid competition w/ house wrens & other cavity nesting songbirds it nests 2-3 weeks earlier, weather permitting
Red-winged blackbird	1. Agriculture 2. Riparian	1. Common breeding resident & spring migrant in agriculture & riparian habitats; uncommon winter resident in riparian habitat	1. Ground & foliage feeder 2. Summer - insectivorous; (weevils, beetles, caterpillars, grubs, rankerworms, grasshoppers, ants, damsleflies) Fall spring & winter - herbivorous; seeds of weeds & crops, (wild rye, ragweed)	1. Incubating eggs in early April. Incubation period - 11 days; 3-5 eggs laid 2. Nestling period - 11 days 3. Nest site - ground & low riparian vegetation- cattails, bunchgrass (Poa sp., Agropyron sp.) & weeds (pigweeds, mustards) 4. Nest structure - grass; cattail or weed cup	1. Adults - great horned owl, short-eared owl 2. Eggs & young - scrub jay, black-billed magpie, common raven, short-tailed weasel, golden-mantled ground squirrel, coyote	1. Consumes hordes of insects destructive to grass & weed species used by cattle, but if present in large numbers can effect the wild-rye, quack grass, & weed abundance used for cattle feed
Green-tailed towhee	1. Mixed brush	1. Common breeding resident	1. Ground feeder 2. Omnivorous - plant material 50% of diet (serviceberry fruit, elksedge, Poa sp., Agropyron sp.) 3. Animal food - Hymenoptera, caterpillars & grasshoppers)	1. Incubating eggs in late May, early June 2. Four eggs laid 3. Nest site - ground nest in serviceberry, sagebrush & Gambels oak 4. Nest structure - loosely constructed grass nest (Poa sp., Agropyron sp.) lined w/feathers & hair	1. Adults - Cooper's hawk, goshawk, sharp-shinned hawk 2. Eggs & young - coyote, scrub jay, common raven, short-tailed weasel	1. Competition w/ Brewer's sparrow, & vesper sparrow for food. Some competition is eliminated by green-tailed towhee's preference for serviceberry & Gambel's oak as nesting & feeding sites & the two sparrow species' preference for sagebrush
Vesper sparrow	1. Bald 2. Upland sagebrush	1. Common breeding resident & migrant	1. Ground feeder 2. Omnivorous; plant material - grasses (Agropyron sp., Bromus sp., Poa sp) & weeds (lupines, mustards) 3. Animal material- ground beetles, grasshoppers, caterpillars, ants & other Hymenoptera	1. Incubating eggs in late April. Incubation period - 12-14 days; 3-5 eggs laid 2. Nest site - ground; sparse open grassy areas among sagebrush 3. Nest structure - forb stems (lupines legumes) & grass stems (Agropyron sp., Poa sp., Stipa sp.)	1. Adults - Cooper's hawk, sharp-shinned hawk, short-eared owl, great horned owl, prairie falcon 2. Eggs & young - scrub jay, black-billed magpie, common raven, short-tailed weasel, golden-mantled ground squirrel, coyote	1. In areas of overlap, it avoids competition w/ other common brushland sparrows by different foraging patterns & strata usage
Sage sparrow	1. Upland sagebrush	1. Common winter resident & fall migrant	1. Ground feeder 2. Primarily herbivorous grass seeds (Agropyron sp., Poa sp., Bromus sp.) & weed seeds (mustards, lupines)	1. Does not breed in this habitat on the study area	1. Adults - merlin, prairie falcon, short-eared owl, great horned owl	1. An abundance of vesper sparrows & breeding sparrows combined w/a limited amount of perennial forbs & grasses is probable cause for absence of breeding individuals
Dark-eyed junco	1. Pinyon-juniper/ mixed brush 2. Mixed brush 3. Bottomland sagebrush	1. Common winter resident & migrant	1. Ground feeder 2. Fall & winter - primarily herbivorous; feeds upon a variety of grass, forb & shrub seeds (pigweed, quack grass, mustards, sagebrush, serviceberry)	1. Does not breed in this habitat or study area	1. Adults - great horned owl, screech owl, short-eared owl, prairie falcon	1. Interspecific flocking occurs during winter w/ gray-headed juncos & house finches
Gray-headed junco	1. Mixed brush	1. Common migrant	1. Ground feeder 2. Primarily herbivorous; forb (legumes), grass (Agropyron sp., Poa sp.) & sedge (elksedge) seeds	1. Does not breed in this habitat or study area	1. Adults - great horned owls, short-eared owl, prairie falcon	1. Utilizes this habitat enroute to wintering habitat in valley bottoms at lower elevation & enroute to breeding habitat in aspen & Douglas-fir

TABLE 3.38 (Continued)

Species	Important Habitats	Status and Occurence	Predominant Food Items and Feeding Habits	Breeding History and Nesting Requirements	Common Predators	Other Important Interactions
Brewer's sparrow	1. Rabbitbrush 2. Bottomland sagebrush	1. Common breeding resident	1. Foliage feeder & ground feeder 2. Primarily insectivorous during spring & summer - beetles & their larvae, grasshoppers, ants, bees, wasps, aphids & other Homoptera, caterpillars & spiders 3. Omnivorous during fall; 53% of diet plant material (pigweed, goosefoot, stickweed, mustards)	1. Incubating eggs during late May, early June. Incubation period - 12-13 days; 3-4 eggs laid 2. Nest site - shrubs (sagebrush, greasewood, rabbitbrush)- close to ground; well concealed 3. Nest structure - small cup of fine grass (cheat-grass, Indian rice-grass) twigs & rootlets (sagebrush, greasewood, rabbitbrush)	1. Adults - great horned owl, short-eared owl, Cooper's hawk, sharp-shinned hawk 2. Eggs & young - scrub jay, common raven, golden-mantled ground squirrel, short-tailed weasel, coyote	1. Avoids competition w/vesper sparrow by primarily feeding in the zone of 1/6m (1/2 ft.) - 2/3m (2 ft.) off the ground, while the vesper sparrow feeds predominantly on the ground
Song sparrow	1. Riparian	1. Common breeding resident & migrant	1. Ground & foliage feeder 2. Spring & summer omnivorous; animal material - beetles, grasshoppers, crickets, caterpillars, ants & other Hymonoptera; plant material - pigwood, quack grass, goosefoot, mustards, sedge 3. Fall - primarily herbivorous	1. Incubating eggs from May-July; commonly raises 2-3 broods. Incubation period - 12-13 days; 4-5 eggs laid 2. Nestling period - 8-11 days; dependent on amount of warm weather 3. Nest site - water-edge vegetation; ground nests in grass (quack grass, Agropyron sp.) cattails & under shrubs (sagebrush & greasewood) are commonest; elevated nests as high as 3.6m (11 ft) in shrubs also occur 4. Nest structure - heavy grasses (quack grass), sedges, & lined w/finer grasses (Indian ricegrass), hair & feathers	1. Adults - great horned owl, short-eared owl, Cooper's hawk, sharp-shinned hawk 2. Eggs & young - garter snake, shrub jay, black-billed magpie, golden-mantled ground squirrel, coyote	1. With many ground feeders present in the riparian habitat (robin,mountain bluebird, the song sparrow probably forages in the 1m (3 ft.)-2m (6 ft.) zone above the ground to avoid competition 2. This species is not present during the winter due to paucity of water in its habitat

1/ Based on literature and extrapolated to site-specific interactions based on investigator's professional judgement.
Pertinent references include:
Bailey and Niedrach (1965)
Bent (1968)
Cody (1979)
Graber, Graber, and Kirk (1971)
Martin, Zim and Nelson (1951)
Skutch (1976)
Welty (1975)
Willson and Orians (1963)

and riparian types resulted in these three types having the highest combined densities for the two fall sampling periods. But, flocking behavior interferes with proper application of the strip transect estimation technique. Discounting these anamalous results, then, the rabbitbrush, bottomland sagebrush, and Douglas-fir types showed the next highest October bird densities for the two years combined. The pinyon-juniper (south slope) and upland sagebrush vegetation types exhibited the lowest overall densities and diversities for the fall sampling periods of both 1974 and 1975. The mountain bluebird, mountain chickadee, gray-headed junco, dark-eyed junco, horned lark, white-crowned sparrow and yellow-rumped warbler were observed in greater numbers than any other species during the autumn surveys.

The October 1974 sampling period probably occurred near the end of the fall migration for most bird species. Some migrating birds such as the mountain bluebird, western meadowlark, and white-crowned sparrow were still present in the study area. A greater number of summer resident species was present during the October 1975 census period. The mild fall weather that occurred during 1975 probably resulted in a later migratory exodus in comparison with the 1974 fall migration.

Due to the harsh winter conditions, avian communities exhibited a trend in decreased utilization of most habitats between the fall and winter periods of 1974-75. The two exceptions to this trend were the Douglas-fir and north slope pinyon-juniper woodland habitats. These habitats supported a greater number of species and individuals during February 1975 than during October 1974. These coniferous forest habitats probably provided a greater abundance of winter food resources and greater protection from the harsh winter conditions than most other habitats during 1974-75.

The milder winter weather conditions prevalent throughout the 1975-76 winter contributed to a greater utilization of the study area habitats by wintering species. The highest species diversity and total density of all habitats during the 1975-76 winter was exhibited by the Douglas-fir and pinyon-juniper/mixed brush habitats. This may be attributed to a better Douglas-fir and pinyon pine cone production and juniper berry production during 1975 than in

1974. The greater availability of these food resources combined with the protective cover provided by the tree stratum made these the preferred habitats of many songbirds wintering on the study area during 1976.

During both winters, the wind-swept bald, and upland sagebrush habitats supported the lowest number of birds and the lowest species diversity. This is a result of these habitats being located at higher elevations and on ridgetops where they are subject to harsher winter weather conditions than the other habitats.

The 1975 and 1976 winter avian communities were characterized by a preponderance of flocking species. Large flocks of dark-eyed juncos were associated with the valley brushland habitats, horned larks were common in the bald, upland sagebrush, and upland mixed brush habitats, and intermixed flocks of mountain chickadees, black-capped chickadees, and red-breasted nuthatches were abundant in the forest habitats during both winter periods.

Flocking species are common in temperate areas that exhibit seasonal fluctuations in food availability (Welty 1975), such as the study area. These flocks are an adaptive mechanism that aids wintering birds in food finding, heat conservation, and protection from predators. In addition, flocking behavior satisfies gregarious tendencies.

The abundant non-flocking species were year-round residents such as the black-billed magpie, pinyon jay, and scrub jay. Members of the family Corvidae are abundant during the winter due to their ability to exploit a wide variety of food resources.

The species diversity, species composition, and density of winter avian communities varied annually and were regulated by winter weather conditions, the abundance of seeds produced during the previous summer, and the abundance of overwintering insects and their larvae.

Results of the April censuses showed a composite of late winter and early spring populations. Many areas showed the uneven pattern of bird distribution typical of the winter, while other areas hosted a considerable variety of species and numbers.

The habitats supporting the largest number of birds and the highest species diversity during the April sampling periods were the riparian, Douglas-fir, bottomland sagebrush, and pinyon-juniper/sagebrush types. During spring migratory periods, songbird species do not exhibit the well-defined habitat preferences and attachments to specific locations shown during the breeding season. Bird distribution during periods of migration often is highly clumped or aggregated and large areas of seemingly appropriate habitat support no birds at a given time while a relatively small area may contain extremely high densities of birds.

Wintering species such as the northern shrike and dark-eyed junco, had begun migration northward by April. The scrub jay, pinyon jay, mountain chickadee, mountain bluebird, yellow-rumped warbler, red-winged blackbird, dark-eyed junco, gray-headed junco, vesper sparrow, and chipping sparrow were the most frequently observed species during the early spring field sampling period. Of these, the mountain bluebird, dark-eyed junco, and gray-headed junco were exploiting a wider range of vegetation types than were other species.

Overall, avian utilization of the study area is greatest during the summer periods. During both summers, the largest number of birds and the greatest species diversity were encountered within the riparian, agriculture, Douglas-fir, aspen, and all pinyon-juniper vegetation types. During June 1976, the rabbitbrush, sagebrush, mixed brush, and bald vegetation types supported fewer species and low total number of birds in comparison with the aforementioned types. This trend was also present in June 1975, but was somewhat less pronounced. Avian utilization of habitat types was generally greater in those habitats that exhibited greater foliage height diversity and plant species diversity.

B. Gamebirds

Three gamebird species are known to inhabit the study area; the sage grouse, blue grouse, and mourning dove. The sage grouse is a common year-round resident within areas of upland sagebrush and mixed brush habitats primarily in the southwest portions of the study area. It also winters in the lower elevations of the study area. Throughout its range on the study area, the

sage grouse is intimately associated with sagebrush the year round. Sage provides winter escape cover and a dominant part of its diet. The distribution of sage grouse populations within the sagebrush and mixed brush habitats on the study area are regulated by sagebrush height and density and topography. Breeding sage grouse populations fluctuated annually. The main factors contributing to the size of the breeding populations is the severity of the winter kill and the abundance of herbaceous material during the spring and summer. Although the actual population size is unknown, Ron Krager of the CDOW (personal communication 1976) stated that the southwest section of the study area appears to support the highest density of breeding sage grouse in the region encompassing Roan Creek and Piceance Creek drainages. The importance of the sage grouse in the study area is related to its economic and recreational value as one of the common gamebird species in the study area. The local sage grouse population probably provides important hunting opportunities in the Piceance Creek and Roan Creek areas.

Blue grouse are common year-round residents along Cathedral Bluffs. In this area, the blue grouse primarily inhabits bald, mixed brush, aspen/mixed brush, and Douglas-fir/mixed brush ecotonal areas. Throughout its range on the study area, it is always in proximity of Douglas-fir stands. Douglas-fir needles, buds, twigs, and cones are major winter food items for blue grouse. As winter ends, the birds migrate from the Douglas-fir stands to areas of more open cover such as the forest-edge habitats. Females generally nest in habitats that provide opportunities for the young to forage on insects and berries.

Relative abundance of summer blue grouse populations on the study area varied annually. This was associated with variations in winter mortality and natural variability in blue grouse breeding populations. The population of blue grouse residing on the study area is probably small in relation to other areas in northwestern Colorado due to the limited amount of preferred blue grouse habitat on the study area.

The importance of the blue grouse on the study area is related to its economic and recreational value as a gamebird.

Interspecific competition between the sage grouse and blue grouse is probably low due to their different preferences for nest sites and food items.

The mourning dove is the most widely distributed gamebird within the study area during the breeding and migration periods. During these seasons, it was observed in a variety of habitats, with the greater number of individuals noted in pinyon-juniper and upland sagebrush vegetation types. Within these habitats, it nests in a variety of substrates. The mourning dove is herbivorous in its food requirements and probably feeds on the variety of herbaceous species found on the study area. Some interspecific competition for food may exist between the mourning dove and other ground-feeding herbivorous passerines during the breeding season.

Recorded dove populations fluctuated annually. These fluctuations may be a result of the time at which the summer censuses were conducted or a manifestation of the natural variability in mourning dove populations on the study area. The population of mourning doves on the study area is probably small in relation to other parts of the Piceance Creek and Roan Creek drainages that have a greater amount of agriculture habitat. Seeds from grain crops are the mourning dove's preferred food and a scarcity of grain seeds exists on the study area.

C. Waterfowl and Shorebirds

In the Tract C-a study area, a few surface ponds and intermittent streams create isolated islands of habitat for waterfowl and shorebirds. Because surface water is restricted in distribution in northwestern Colorado, such habitat types have an unusually high ecological value in this region. Fourteen waterfowl and shorebird species were recorded within the Tract C-a vicinity, primarily associated with the Stake Springs draw impoundment. Although usage of the area by waterfowl and shorebirds is greater during late spring and summer than during fall, the overall waterbird population within the study area is small. The paucity of open water is undoubtedly a major limiting factor on the size of the resident migratory waterfowl populations. The mallard, green-winged teal, blue-winged teal, and killdeer were the most common waterfowl and

killdeer were the most common waterfowl and shorebirds utilizing surface waters of the area.

Two migrant shorebird species unusual to the study area, the greater sandhill crane and whooping crane, were observed during spring and fall investigations. The population of greater sandhill cranes that nest within Colorado has been recognized as "endangered" by the CDOW. This designation does not apply to populations stopping temporarily within Colorado during migration periods. The whooping crane is classified as an endangered species on the 1975 federal list of endangered and threatened species (USDI 1975). An endangered species is one that is in danger of extinction throughout all, or a significant portion of, its range.

Observations of these species were largely on 84 Mesa, at the Stake Springs Draw impoundment and in the agriculture habitat along Yellow Creek. The locations of these sightings are mapped on Figure 3.43 of RBOSP Progress Report 10 (1977).

D. Raptorial Birds

Raptorial birds include the vultures, hawks, eagles, falcons, and owls. Also included in this category, due to its similar ecological role, is the common raven (Craighead and Craighead 1969). The status, occurrence and number of nests located on the study area for all raptor species known to occur on the study area are presented in Table 3.39. Distribution maps of all raptor species known to occur on the study area are depicted in Figures 3.44 - 3.48 of RBOSP Progress Report 10 (1977). These maps depict the collated results of all opportunistic raptor sightings and night owl survey observations that were recorded during the two-year baseline program. All cliff sites of 10 m (30 feet) or higher were located by remote sensing methods, and have been identified as potential raptor nest sites on the study area. These areas are depicted in Figures 3.49 and 3.50 of RBOSP Progress Report 10 (1977).

Fourteen diurnal hawk, vulture, eagle, and falcon species, six nocturnal owl species, and the common raven are the raptor species that have been recorded on the study area. Two species only occur on the study area during migration and

TABLE 3.39

RAPTOR SPECIES NOTED ON RBOSP TRACT C-a STUDY AREA DURING 1974-1976

Species	Seasonal Occurrence	Status	Number of Active Nests Located 1975	1976
Turkey vulture	Summer resident	Rare	0	0
Goshawk	Permanent resident	Rare	1	0
Cooper's hawk	Summer resident	Uncommon	2	0
Sharp-shinned hawk	Summer resident	Rare	0	1
Marsh hawk	Permanent resident	Common	3	0
Rough-legged hawk	Winter resident	Uncommon	0	0
Red-tailed hawk	Permanent resident	Common	7	3
Swainson's hawk	Summer resident	Rare	0	0
Golden eagle	Permanent resident	Common	2	2
Bald eagle	Winter resident	Uncommon	0	0
American kestrel	Permanent resident	Common	8	1
Prairie falcon	Permanent resident	Uncommon	0	0
Peregrine falcon	Migrant	Rare	0	0
Merlin	Migrant	Rare	0	0
Great horned owl	Permanent resident	Common	7	1
Screech owl	Permanent resident	Uncommon	0	0
Long-eared owl	Permanent resident	Uncommon	0	0
Short-eared owl	Permanent resdient	Common	0	0
Saw-whet owl	Permanent resident	Uncommon	0	0
Pygmy owl	Permanent resident	Uncommon	0	0
Raven	Permanent resident	Common	3	2
			33	10

Definitions of terms used to describe seasonal status are as follow:

Seasonal occurrence

permanent resident: a species present in the study area during all seasons.

summer resident: a species present in the study area throughout the summer, and assumed to nest in the area.

winter resident: a species present in the study area during winter only.

migrant: a species present in the study area only during migration.

Definitions of terms used to describe status follow:

Status

Common: a species noted regularly in its normal habitat at the proper season of the year.

Uncommon: a species of regular occurrence in small numbers, at the proper season of the year, but not likely to be observed on every census.

Rare: a species present in small numbers, and noted only seldomly in proper habitat.

two species are winter residents. The abundant year-round residents of the study area were the golden eagle, red-tailed hawk, American kestrel, great horned owl, and common raven. Due to their year-round abundance, these species were designated as the important raptor species on the study area.

Raptors were distributed throughout the study area. However, the majority of species were associated with the drainages in the lower elevations. The pinyon-juniper woodland and rimrock areas on the slopes adjacent to the drainages provide numerous potential nest and perch sites for many species. The bottomland sagebrush and agriculture bottoms support abundant small mammal populations, the predominant prey base of most raptor species nesting and wintering on the study area.

Thirty-six active raptor nest sites and 21 inactive nests were located on the study area during the two-year raptor nest survey. Nests of nine raptor species were found on the study area and at least eight other species are expected to nest on the area but their nests have not yet been located.

The major factor limiting the wintering and breeding populations of the various raptor species on the study area is the availability of food items, particularly deer mice, microtines, lagomorphs, and deer carrion.

Minimum territory size requirements exhibited by many raptor species, such as the great horned owl, also regulates the abundance of raptor populations on the study area.

Some interaction between raptors and other bird groups on the study area exist. Songbirds, upland gamebirds, and waterfowl species probably constitute a portion of the diet of some raptor species on the study area. Also, the golden eagle, bald eagle, common raven, and turkey vulture probably compete with other members of the Corvidae family for scavengeable prey, particularly during the winter. For example, common ravens have been observed on the study area chasing black-billed magpies away from carrion that the common ravens then proceeded to consume.

V. REPTILES AND AMPHIBIANS

The objectives of the reptile and amphibian sampling program were to determine habitat preference, distribution, and, when possible, abundance of species of reptiles and amphibians occuring on and near Tract C-a. The development of a concept of the ecological role and importance of reptile and amphibian species locally was an additional goal of the sampling program.

Reptiles were sampled during 40 line transect surveys evenly distributed among four sampling periods over the two-year baseline program. Results summarized over the two-year period are presented in Table 3.40. One hundred fifty-nine reptiles representing four species of lizards and one snake species were observed during these surveys. The most abundant reptile species per unit of sampling effort was the sagebrush lizard (47 percent, followed closely by the tree lizard (42 percent). The sagebrush lizard was also the most widespread reptile on the study area, appearing in 84 percent of all transects for which reptiles were recorded. Habitats showing the highest abundance and diversity of reptiles were open, south-facing slopes with ledges and rock piles for basking and shelter and with a few scattered bushes and deadfall for additional refugia. The limited amount of this habitat in the study area results in a fairly low reptile population density and diversity averaged over the entire area. Several expected species were not discovered due to their absence or very low abundance in the study area.

Amphibians were sampled two nights in May and June of both years, when breeding sites (ponds) were visited and breeding calls recorded as to species. Two species, the chorus frog and the Great Basin spadefoot, were heard calling at two locations each year. In addition, numerous tiger salamander larvae were observed both years in the Stake Springs pond. The chorus frog appeared to be the most numerous and widely distributed amphibian on the study area. Three expected species were not encountered either due to unfortunate timing of breeding site visits or due to their absence locally. In general, the abundance and diversity of amphibian species in the area are severely limited by the scarcity of suitable amphibian habitat.

Neither reptiles nor amphibians occur in sufficient numbers to have a noticeable effect on their prey species. Similarly, this low abundance also prevents reptiles and amphibians from serving as a primary or obligate food source for

TABLE 3.40

HERPETOFAUNA LINE TRANSECT RESULTS BY HABITAT TYPE CORRECTED FOR INTENSITY OF SURVEY EFFORT IN THE VICINITY OF TRACT C-a DURING FOUR SAMPLING PERIODS FOR RBOSP

Habitat Type	No. of Surveys	Average Observations per Survey/ % Relative Abundance Within Type[1]					Average Reptile Observations per Survey	Percent of Total Observations
		Sceloporus graciosus	Sceloporus undulatus	Urosaurus ornatus	Phrynosoma douglassi	Thamnophis elegans		
Rocky-cliff/Gully sidehill	2	6.5/20	4/13	21/67	0	0	31.5	57.0
Pinyon-Juniper	10	5.5/96	0	0	0.2/4	0	5.7	10.0
Pinyon-Juniper/Sagebrush	2	11/79	1/7	2/14	0	0	14.0	25.0
Shadscale	2	2/100	0	0	0	0	2.0	4.0
Upland Sagebrush	5	0.2/25	0	0	0.6/75	0	0.8	1.0
Greasewood/Sagebrush	4	0.5/100	0	0	0	0	0.5	1.0
Riparian	2	0	0	0	0	0.5/100	0.5	1.0
Bottomland Meadow	1	0	0	0	0	0	0	0
Upland Meadow	2	0	0	0	0	0	0	0
Rabbitbrush	1	0	0	0	0	0	0	0
Mixed Brush	5	0	0	0	0	0	0	0
Pinyon-Juniper/Mixed Brush	1	0	0	0	0	0	0	0
Bottomland Sagebrush	1	0	0	0	0	0	0	0
Aspen	1	0	0	0	0	0	0	0
Douglas-Fir	1	0	0	0	0	0	0	0
% Relative Abundance[2]		47	9	42	1	1		

[1]Percent values rounded to nearest whole percent so totals may in some cases exceed 100%.

[2]Corrected for sampling intensity.

any predator species. The western terrestrial garter snake probably comes closest to relying on other herpetofauna for an important proportion of its food; however, this snake preys on several invertebrate groups, fish, small mammals, and occasionally birds as well as amphibians and other reptiles.

Several species of amphibians and reptiles were expected but not found in the study area. It is likely that many, if not most or all, of these species are not present locally because of microhabitat limitations or severe climatic conditions preventing or greatly retarding their invasion and establishment. It is possible that some of the expected species are present in low numbers but were not observed because their presence and activity did not coincide with those of the field observers.

VI. INVERTEBRATES

The objectives of invertebrate sampling in the Tract C-a study area were to collect and identify the abundant invertebrates associated with the major vegetation types, qualitatively and quantitatively describe the invertebrates whose hosts are made up of the dominant plant species within these vegetation types, and determine the major relationships of invertebrates with their environments.

Invertebrates were sampled in five of the most common vegetation types in the study area; bottomland sagebrush, north and south slope pinyon-juniper woolands, upland sagebrush, and mixed brush. A variety of sampling methods was used to identify the numerically abundant invertebrates within each vegetation type. These consisted of pitfall traps, litter vacuuming, trap D-Vac samples from one or more of the dominant shrub species, herbaceous vegetation sweeping, and a malaise trap at each of the five sampling sites. In bottomland sagebrush and pinyon-juniper/north and south slope sites, aerial sweeps and beating samples were also taken from trees or large shrubs.

Harvester ant (*Pogonomyrmex occidentalis*) colony density in the study area was determined by counting numbers of colonies per hectare from 1:6000 scale color infrared photographs.

The invertebrate fauna present in each sampled vegetation type were categorized according to the stratum in which they were captured. The ground stratum includes the above ground or surface fauna sampled by pitfall traps, and the litter, or subsurface, fauna which was obtained by vacuuming the litter found under one or more dominant plant species in each vegetation type. The vegetation stratum fauna is composed of all invertebrates captured from selected herbaceous, shrub, and tree species found in each habitat type. This includes all invertebrates captured in herbaceous sweep, trap-vacuum, aerial sweep, and beating samples. The aerial stratum is occupied by invertebrates which are actively flying within each sampled vegetation type and consists of those invertebrates captured in malaise traps.

Total invertebrate captures were greatest over the two-year sampling program (1975-1976) from the pinyon-juniper/south-slope vegetation type where 65,667 invertebrates were captured (Figures 3.7 and 3.8). This total included more than 40,000 springtails of the species Isotoma cinerea taken in May 1976. A comparison of capture totals for each sampling period of 1975 and 1976 indicated that invertebrate activity was consistently higher in the bottomland sagebrush and mixed brush vegetation types than in any other types sampled. Peaks in capture totals occurred primarily in June 1975 and July 1976 for all vegetation types sampled. The yearly trends in captures from each vegetation type reflect the influence of weather conditions prior to and during the 1975 and 1976 sampling seasons on the hatching success of invertebrate groups active in early summer. These families emerge in early summer because moisture and temperature conditions are usually best for reproduction and development of immatures that require high moisture levels. Field notes for the 1975 and 1976 sampling seasons indicate that snow was present in greater amounts in the vicinity of Tract C-a later into the spring in 1975. More rain was also observed in May and July 1975, along with increased cloud cover and generally more moderate temperatures. Less snow and rain were observed in the spring and early summer of 1976, presumably lessening the availability of free-standing water and soil moisture during the May 1976 sampling period. Temperatures were moderate in May 1976, but in July and September daily temperatures frequently went above 32 C and moisture was provided by only a few scattered afternoon rain showers.

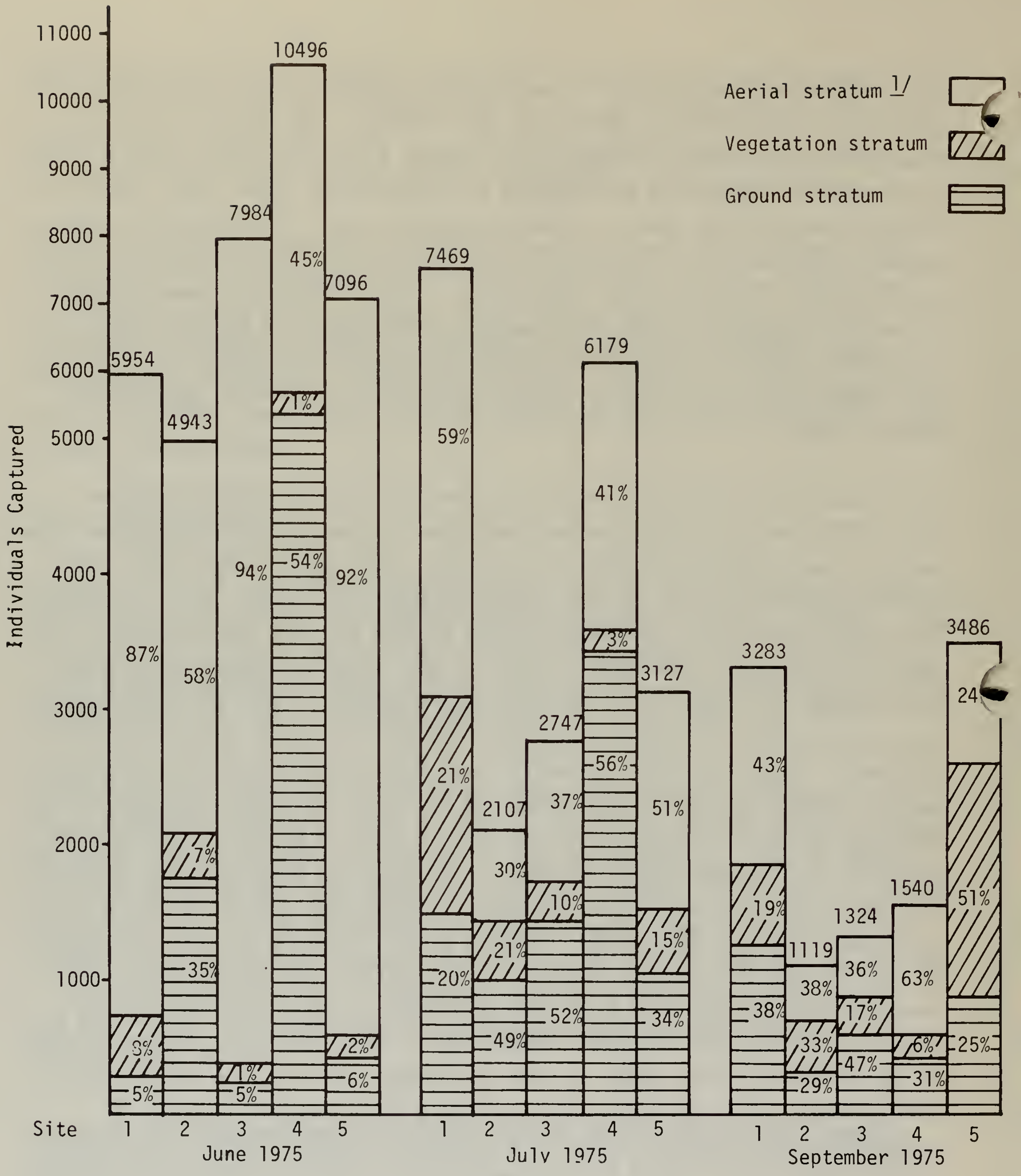


FIGURE 3.7
INVERTEBRATE CAPTURE TOTALS SHOWING PERCENT RELATIVE ABUNDANCE IN EACH STRATUM FOR THE FIVE HABITAT TYPES SAMPLED IN 1975 FOR RBOSP

1/ Stratum definitions given on page

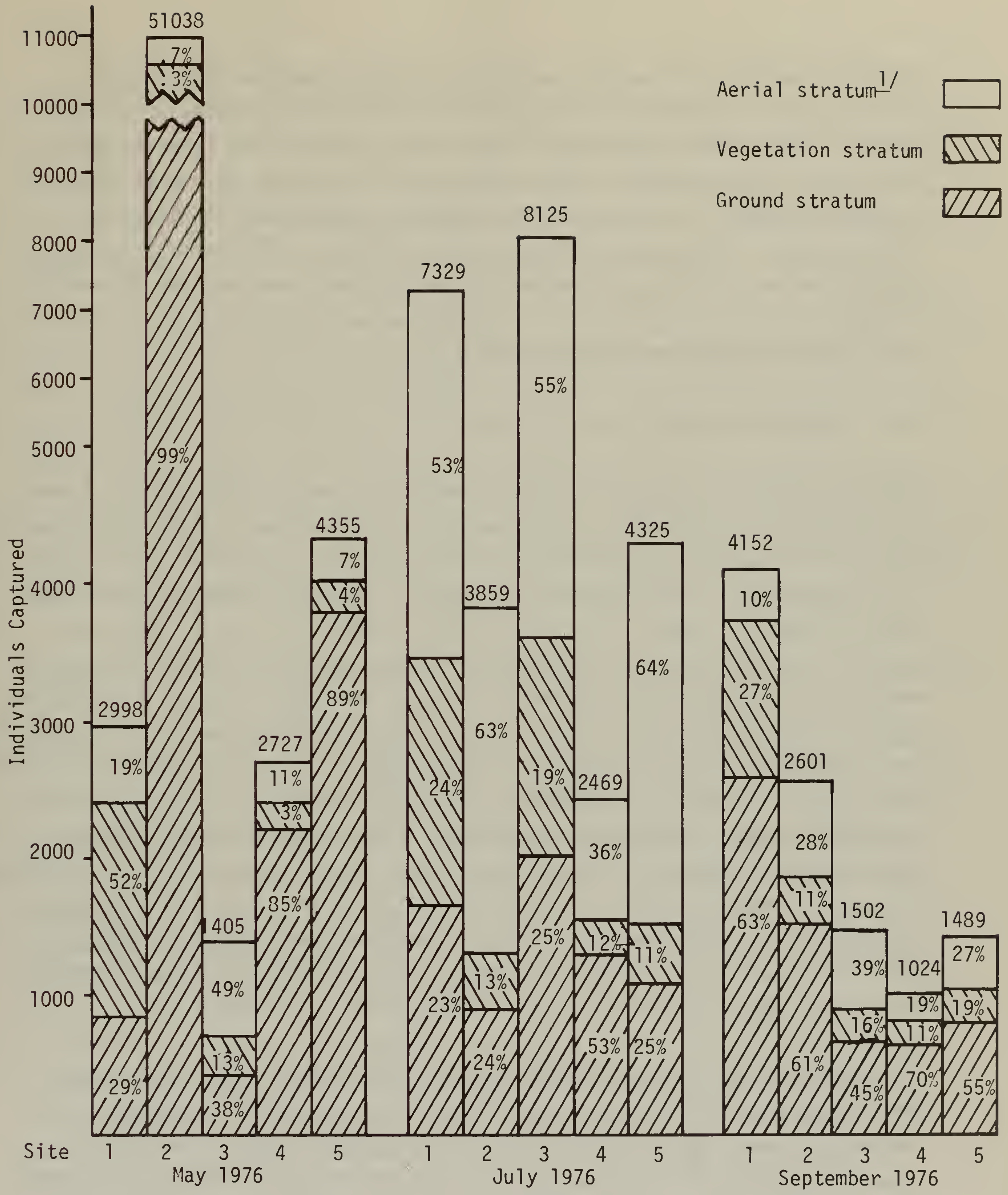


FIGURE 3.8
INVERTEBRATE CAPTURE TOTALS SHOWING PERCENT RELATIVE ABUNDANCE IN EACH STRATUM FOR THE FIVE HABITAT TYPES SAMPLED IN 1976 FOR RBOSP.

1/ Stratum definitions given on page

Abundant moisture in the winter and spring prior to the June 1975 sampling period probably accounted for large numbers of successful emergences of chironomids, fungus gnats, dark-winged fungus gnats, and stiletto flies in nearly every habitat type sampled. Drier, warmer conditions prior to the 1976 season limited the numbers of successful early summer emergences by the above mentioned groups. Conversely, colder conditions prior to 1975 sampling reduced hatching and activity of surface- and litter-dwelling invertebrates (primarily springtails) in June 1975. In 1976 these groups were able to hatch at a much earlier date and were abundant and active by May.

A. Ground Stratum

Trends in activity of ground stratum invertebrates were closely tied to changes in the physical environment in all vegetation types sampled. Nightly temperatures were generally cooler in the valleys of the study area, resulting in higher absolute and relative humidities compared to the slopes and ridgetops where other sampled vegetation types occur. The higher humidities and the intermittent presence of flowing water in the bottomland sagebrush area made more moisture available on the surface for longer portions of the season relative to the other habitat types sampled. The dense vegetation and relatively deep litter at the bottomland sagebrush site, also contributed to moisture retention for longer periods into the summer, resulting in continued activity of the numerically dominant groups (Liposcelis liparus, Liposcelis formicarius, and Entomobrya griseo-olivata) throughout both 1975 and 1976 sampling seasons. Daily relative humidity measurements during all sampling periods indicate that high relative humidity also partially accounted for the presence and activity of the harvestman Homolophus biceps in 1975. This species is extremely intolerant of desiccation and is found only in areas where humidity attains 90 - 100 percent levels during each day.

Surface and litter moisture were readily available only in the early summer sampling periods at the pinyon-juniper/south slope and upland sagebrush vegetation types. These two sites were also warmed to levels conducive to insect development much earlier in the season than other vegetation types sampled because of their exposure and relative lack of vegetation cover. By July of both years, however, increased temperatures and decreased moisture availability

caused the litter and soil surface to be too hot and dry for sustained activity of desiccation-intolerant soft-bodied invertebrates which made up the majority of the captures from the ground stratum of the pinyon-juniper/south slope and upland sagebrush vegetation types. As a result, springtails were captured in abundance only in the early summer sampling periods of 1975 and 1976. Isotoma cinerea and Xenylla grisea were very abundant on the surface and subsurface respectively in the early summer at the pinyon-juniper/south-slope site. By July only I. cinerea was collected, and specimens were found only in deep pinyon pine litter where numbers of the species has concentrated to avoid the extremes in temperature and moisture loss. Hypogastrura armata, the abundant springtail in the upland sagebrush-habitat ground stratum, was common in the early summer sampling period of 1975 and 1976, but was generally not captured on the surface or in the litter in July of either year. An exception did occur in July 1976 when one sample from an uncharacteristically deep litter area contained a large number of H. armata which had concentrated in the protected location. When temperatures dropped and moisture levels increased in the litter in September 1976, H. armata was found in all litter samples.

Surface and litter temperatures at the pinyon-juniper/north-slope habitat were lower in the early summer relative to the south slope pinyon-juniper site because of the protection from the sun's heat afforded by the northerly aspect and increased tree canopy cover. The lower temperatures may have inhibited matching and development of collembola in the early spring, explaining the absence of X. grisea from early summer samples at the north slope pinyon-juniper site. These same factors (aspect and tree canopy cover) allowed increased moisture retention in the soil and decreased temperatures in July 1975 and 1976 at the north slope pinyon-juniper site, relative to the south slope site, resulting in the majority of X. grisea captures during midsummer.

The mixed brush habitat surface-active springtail species, X. grisea, exhibited the same trends as springtails in the pinyon-juniper/south slope and upland sagebrush habitats in peaking in the early summer period of 1975 and 1976. The absence of X. grisea from the ground surface of the mixed brush site in July and September 1975 and 1976 was also characteristic of the species in the pinyon-juniper/south slope and upland sagebrush vegetation types. The X. grisea capture data from all three vegetation types suggest that the species is in-

tolerant of dry conditions relative to other springtail species captured, and is active on the surface only during the spring and early summer when relative humidities on the surface approach 100 percent. The litter layer, particularly under serviceberry, was very deep and retained sufficiently high moisture levels and mild temperatures throughout both seasons as demonstrated by the nearly constant density of *Entomobrya griseo-olivata* in nearly all sampling periods.

Mites were the only other invertebrate group consistently abundant in the ground stratum of all vegetation types sampled. Mite captures increased on the surface and in the litter of all vegetation types in 1975 and 1976, suggesting that this order has an ability to withstand desiccation. Mites actively reproduced and increased population sizes as the summer progressed despite the progressive seasonal increase in temperature levels and decrease in moisture availability.

The primary importance of springtails, mites, booklice, and other less abundant litter and surface dwelling microarthropods is their role in detritus breakdown and nutrient recycling. These saprophytic feeding groups are important in the detritus breakdown process in several ways. Invertebrate saprovores break down detritus to components directly useable by the producer trophic level (plants). They also increase fungal breakdown of detritus by cropping off hyphae, thereby keeping the fungi at maximum levels of new growth production and detritus breakdown. Saprophytic invertebrates also break down detritus to components useable by microorganisms which ultimately return the mineral and organic products back to the soil for plant useage. Seasonal fluctuations in the abundance and activity of saprophytic invertebrate groups suggest that detritus breakdown at the invertebrate level may have also fluctuated as the 1975 and 1976 seasons progressed. Greatest fluctuation in invertebrate saprovores occurred in the pinyon-juniper/south-slope habitat where *I. cinerea* captures decreased from over 40,000 individuals in May 1976 to only a few captures in July.

B. Vegetation and Aerial Strata

Invertebrate feeding in the vegetation stratum appeared to have visibly affected only a few of the plant species sampled or observed in vegetation types sampled. Rabbitbrush, one of the dominant shrub species in the bottomland sagebrush habitat, was fed upon by a variety of herbivorous insects which feed on all parts of the plant. Foliage was attacked by *Anthonomus tenuis*, *Epimechus modicus*, *Leptothrips* sp., and *Haplothrips* sp., while roots were no doubt fed upon by larvae of *A. tenuis* and *E. modicus*. The greatest effect of insect herbivory was in feeding on flower parts by *Leptothrips* and on unknown checkered beetle species which were observed in large numbers on the flowers in late summer. The net feeding effect by the two species possibly reduced seed production. Rabbitbrush also appeared to be the species most affected by invertebrate feeding of the plants sampled by herbaceous sweeping at the mixed brush site. Extremely large numbers of aphids were present on the plants in July and September 1975, potentially removing large quantities of plant sap. In so doing, the aphids weaken the plants, reducing accumulation of vegetative biomass and causing leaves and flowers to dry up prematurely.

Leptothrips sp. was also captured abundantly from sagebrush and ryegrass at the bottomland sagebrush site, possibly resulting in reduction of optimum biomass accumulation by the plants because of sap removal and plant cell destruction.

Sagebrush was also affected by invertebrate feeding at the pinyon-juniper/ north-slope and upland sagebrush habitatis, as well as in the bottomland sagebrush vegetation type. Visible damage was primarily due to galls produced by a number of gall midges, notably *Diarthronomyia artemisiae*. A few sagebrush plants at all three sites (upland, bottomland sagebrush, and pinyon-juniper/north slope) appeared to be near death as a result of heavy attack by *D. artemisiae*.

Sagebrush flowering buds were attacked by *Frankliniella occidentalis* which burrowed into the forming buds and fed on developing pistils and stamens, affecting seed production at all sites where sagebrush was sampled. Roots of sagebrush were affected by feeding of several invertebrate groups including *Orthezia artemisiae* and several broad-nosed weevils. The cumulative effect of these groups was to destroy root tissue needed for absorption of water and nutrients,

resulting in reduction of optimum growth and less healthy plants overall.

Ryegrass was most affected by insect feeding of all plant species sampled in all vegetation types in 1975 and 1976. Seed bugs and chloropid flies were taken in large numbers from the ryegrass-dominated herbaceous vegetation at the bottomland sagebrush habitat. Both families inhibit seed formation by feeding on developing seeds (Lygaeidae) or in the culms of flowering heads (Chloropidae).

Aelothrip auricestus was also abundant from herbaceous sweep samples of the ryegrass-dominated understory of the bottomland sagebrush site. The present of the species primarily in July of both years indicates that it may have been actively feeding on flower parts of ryegrass which reached anthesis in July. The combined feeding effect of the three above-mentioned insect groups and heavy cattle grazing on ryegrass in the sampling area probably results in very low seed production level and growth of new ryegrass seedlings in the bottomland sagebrush habitat.

Shadscale was the plant species least affected by invertebrate feeding of any shrub sampled judging from the low total insect captures from this shrub during the two-year sampling program. Orthezia annae was the only species found consistently on the plants sampled. Low capture totals per plant precluded extensive damage.

The appearance of large numbers of aphids in September 1975 on prickly phlox in the pinyon-juniper/south-slope habitat indicated a substantial feeding effect on the plants observed. Permanent damage did not occur because several seasons of heavy attack are needed and aphids were not observed on prickly phlox in 1976.

Sample results and visual observations of pinyon pine and juniper throughout the study area revealed little damage and few tree deaths which could be attributed to insects. The most visible signs of insect attack on pinyon pine were from needle miners (Recurvaria sp.), which inhabited approximately 5 - 10 percent of the needles examined, and pine needle scale, which was widely observed although

low in abundance per tree relative to numbers needed to cause extensive damage given in the literature (Little 1943; Felt 1965). Herbivorous insects suspected to be feeding on juniper were low in total numbers and diversity, supporting the theory that chemical substances in juniper may inhibit insect feeding (personal communication, T. O. Thatcher, Utah State University, April 1976).

Herbivorous activity on serviceberry and snowberry in the mixed brush habitat for the most part was low in nearly every sampling period. Serviceberry seed production was reduced through bud feeding by the western flower thrips (F. occidentalis) in May 1976, and the foliage was somewhat affected by several gall species of which Trishormomyia canadensis was the most commonly observed. Snowberry sampling yielded no invertebrate herbivore groups abundant enough to cause extensive defoliation or sap reduction through feeding. The only other evidence that the two shrub species were affected by insect feeding was the presence of occasional aggregations of Hemilueca sp. and Malacosoma cisstria caterpillars which had completely defoliated the plants which they inhabited. Permanent damage did not occur because the same plants were not attacked in successive years, and overall reduction in biomass of the serviceberry and snowberry in 1975 was not substantial as the caterpillar aggregations were present on only a few of the shrubs in the mixed brush vegetation type.

The invertebrate groups most important to the dynamics of ecosystem function in the study area were those families involved in pollination or population control of other invertebrate groups through parasitism. A variety of abundant and less abundant insect families were captured in all vegetation types sampled, which contributed through pollination to the reproductive success of many plant species in the study area. Many dipteran families captured abundantly in all vegetation types sampled, including chironomids, fungus gnats, and gall midges, played a part in pollination because of their large numbers although they are considered inefficient pollinators. Other abundant families, including syrphid flies, anthomyiid flies, bee flies, and butterflies and moths, which feed on nectar regularly and were common at all sites, also acted as pollinators in their daily flower visits.

The most efficient pollinators captured were members of the bee superfamily (Apoidea). The bee families Apidae and Halictidae were the most commonly captured from all vegetation types sampled. Bee captures were highest overall in the early-summer sampling periods of 1975 and 1976, corresponding with the peak in the flowering of insect pollinated plant species. The high numbers and variety of bees in the pinyon-juniper habitats probably result from the abundance of dead trees and suitability of the soil for burrowing providing many suitable nesting locations within flying distance of more open habitats which contain a greater diversity and abundance of nectar-producing plants. By contrast, high numbers and variety of bees in the upland sagebrush habitat in the early summer were a result of the great variety of insect pollinated flowering plants in that vegetation type.

A variety of wasp and fly families present in the vegetation and aerial strata also exert some influence on the vegetation because their larval stages are parasitoids of herbivorous invertebrates. Braconoidea and Chalcidoidea wasp families were the parasitic groups most often captured in the study area, particularly ichneumonid wasps, braconid wasps, platygasteried wasps, and pteromalid wasps. All vegetation types sampled except the upland sagebrush site contained large numbers and variety of parasitic wasps in the vegetation and aerial strata. The most visible parasitic wasp-host relationship at all sites in the study area was the presence of large numbers of platygasterid wasps in every habitat type where sagebrush was one of the dominant shrub species. Members of this family are parasites of gall midges which were most visible and abundant on sagebrush. Samples from sagebrush at the bottomland sagebrush, upland sagebrush, and north slope pinyon-juniper sites contained platygasterid wasps in nearly every sampling period of 1975 and 1976. In certain sampling periods (notably September of both years), the platygasterids contributed greater than 5 percent of the total insect captures from sagebrush. It would appear that the relatively high capture totals of platygasterids, and the the fact that the species is polyembryonic, results in considerable reduction in the numbers of gall midges in the vegetation types where sagebrush was found (upland sagebrush, bottomland sagebrush, and pinyon-juniper/north slope). The variety and abundance of parasitic wasp species which are host-species specific in the study area suggests they contribute

to the population control of a variety of herbivorous insects feeding on the vegetation of the study area.

Western Harvester Ants

Western harvester ant colonies were associated primarily with sagebrush dominated vegetation types in the study area. Highest densities were counted in the upland sagebrush habitat of 84 Mesa (2.04 colonies/ha), ridgetop upland sagebrush habitat (1.49 colonies/ha), and bottomland sagebrush (1.89 colonies/ha). Calculations of seed consumption per acre of harvester ants from the literature (Lavigne and Fisser 1961) were used as a basis for approximating seed loss in the above mentioned vegetation types. Roughly one pound of seed per acre is taken by harvester ants in the 84 Mesa upland sagebrush vegetation type.

CHAPTER 6 - VEGETATION, SOILS, AND WILDLIFE OF THE AREA

A two-year terrestrial baseline study was conducted on the RBOSP study area (Tract C-a and the area within five miles of the tract boundary) in the Piceance basin. The primary objective of this study was to define the existing terrestrial ecosystem in the vicinity of Tract C-a. Data collected were assessed to define baseline conditions in the study area prior to oil shale development.

The study area lies in the west-central portion of the Piceance basin and includes about 110,000 acres. Pinyon-juniper associations were the dominant vegetation type in 41 percent of the area, and together with mixed brush and sagebrush, occupied 93 percent of the area. Eight additional vegetation types occurred in the remaining 7 percent of the area. The three dominant vegetation types on Tract C-a are also common in the Piceance basin. These three vegetation types occupy 70 percent of the 2,050,481 acres in the Piceance Basin (BLM & CDOW 1977). Table 3.41 shows the extent of the vegetation types in the study area compared to those in the Piceance Basin Habitat Management Area.

Soils in the study area had chemical and physical properties typical of semi-arid regions in the western United States. Four soil types (Rentsac, Rentsac-Piceance, Rock Outcrop-Torriorthent, and Glendive) were dominant, occupying 90 percent of Tract C-a. Torriorthent was the only series that was saline near the surface; shadscale was the dominant vegetation on these soils. The Glendive soils, which occupied alluvial valley bottoms, had the best balance of nutrients and the greatest surface soil depth; bottomland sagebrush occurred on these soils. The Rentsac and Rentsac-Piceance types were the most common soils on Tract C-a and supported sagebrush and pinyon-juniper. The limited correlation between the 46 soil traits (e.g., depth, organic matter) on Tract C-a (Chapter 3) indicated little if any relationship between traits. A cluster analysis by sampling location (Chapter 3) indicated that characteristics of the soil series were generally similar. This may account for the fact that several vegetation types were often found on the same soil type.

TABLE 3.41

COMPARISON OF THE EXTENT OF VEGETATION TYPES IN THE RBOSP STUDY AREA AND IN THE PICEANCE BASIN HABITAT MANAGEMENT AREA

Vegetation Types	Piceance Basin Habitat Management Area (Acres)	RBOSP Study Area (Acres)
Douglas-Fir (Conifer)	210,118	1,598
Aspen (Broadleaf)	165,760	961
Mixed Brush	373,798	27,389
Pinyon-Juniper	589,160	45,169
Sagebrush	463,483	29,468
Greasewood	19,200	1,087
Saltbush	22,080	1,280
Riparian	32,480	185
Half-Shrub	1,638	
Grassland	105,360	2,087
Waste	27,321	
Agricultural	40,083	847
	2,050,481	110,071

General interrelationships between selected biotic components of the terrestrial ecosystem on Tract C-a are outlined in Figure 3.9. Some species or faunal groups (e.g., songbirds) are omnivorous and their food habits change seasonally depending on food availability. Figure 3.9 is a general diagram of energy flow through various trophic levels; species shown for the various trophic levels were typical, in the appropriate habitat, within the Tract C-a study area.

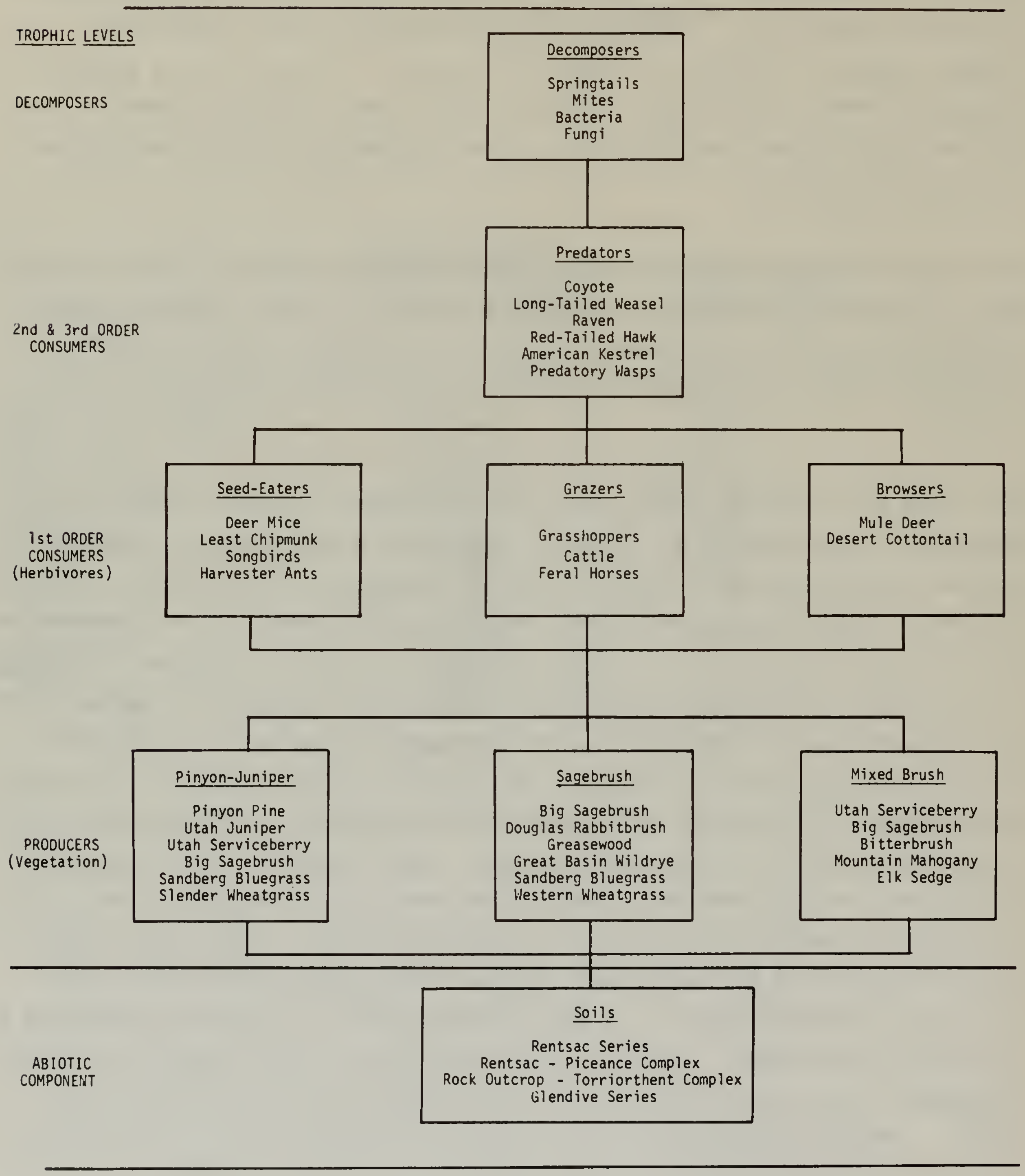
The three dominant vegetation types (pinyon-juniper, sagebrush and mixed brush) were structurally diverse and supported a variety of animal species. The heterogeneity within sagebrush, mixed brush, and pinyon-juniper habitats (Chapter 3) made it difficult to quantitatively describe components of these habitats.

The study area provided forage and browse for domestic animals and wildlife. Rangeland in the study area, primarily sagebrush, mixed brush and pinyon-juniper, was classified as being in fair (73 percent) or poor condition (24 percent). Forage production (Kg/ha; dry weight) was about 304 in sagebrush, 234 in mixed brush and 114 in pinyon-juniper. Utilization exceeded 30 percent in mixed brush and pinyon-juniper but was less than 10 percent in sagebrush. The carrying capacity of Tract C-a for cattle was estimated to be 600 AUM's. Principal large grazers on Tract C-a were cattle and feral horses. The northwest one-half of the tract is in the Box Elder (grazing). Allotment and the remaining portion is the Squares Allotment. Cattle were on tract from approximately May through November. Feral horses were in the study area year-round and probably competed with cattle for available forage. Horses were common in the area bounded by Big Duck Creek, Yellow Creek, Stake Springs Draw (Left Fork), and Cathedral Bluffs. It was estimated that the study area supported at least 135 feral horses. The RBOSP study area lies in the Piceance Wild Horse Management Unit which is believed to contain about 240 horses (BLM & CDOW 1977). Therefore, approximately 55 percent of the feral horses in this unit occurred, at least for some period of time, on or in the vicinity of Tract C-a.

Browse condition for pinyon-juniper and mixed brush in the study area was

FIGURE 3.9

DOMINANT SPECIES IN EACH BIOTIC COMPONENT OF THE TERRESTRIAL ECOSYSTEM ON RBOSP TRACT C-a



considered good. Tract C-a is apparently transitional range for mule deer that is utilized during spring and fall migrations; it may also be used during mild winters. Important browse species (i.e., common and used) in mixed brush and pinyon-juniper habitat included bitterbrush, serviceberry and mountain mahogany. Tract C-a lies in CDOW's Game Management Unit (GMU) 22 which encompass 1,033 square miles. The CDOW estimated winter mule deer populations in GMU 22 at about 26,000 animals (BLM & CDOW 1977). Aerial counts of mule deer over the Tract C-a study area indicated that deer were most common to the east of the Tract from January through April (76-491 observed per hour) and to the west of the tract during November and December (10-237 observed per hour).

The Tract C-a study area provided food and shelter for a variety of animals. Of the three dominant vegetation types, the pinyon-juniper associations had the highest diversity of small mammals. Least chipmunk and deer mouse were the most commonly captured species and pinon mouse, Colorado chipmunk, and bushy-tailed woodrat were generally limited to this vegetation type. This may reflect the availability of food and cover for small mammals in pinyon-juniper associations. Avifauna sampling showed that higher numbers of species and individuals used the pinyon-juniper associations during the winter than most other habitats, and that this vegetation type was used as nesting habitat by several species of birds, including mourning dove and gray-headed junco. In general, the pinyon-juniper vegetation type provided habitat for many animals and was particularly important as winter cover for mule deer.

The sagebrush vegetation type on Tract C-a included the upland and bottomland associations. Faunal diversity and abundance differed somewhat between these two associations. Some small mammal species were captured more frequently in sagebrush than in other types; however, no small mammals were found only in sagebrush. The white-footed mouse and the least chipmunk were the most commonly captured small mammal species in upland and lowland sagebrush. Sagebrush was apparently less important to mule deer for browse and cover than were the other two dominant vegetation types. The sagebrush vegetation type provides cover and a major portion of the food required by sage grouse. An area southwest of Tract C-a was estimated to have the highest density of breeding sage grouse

in the Roan Creek and Piceance Creek drainage. Other birds that nested in sagebrush included Brewer's sparrow, vesper sparrow, chipping sparrow, and green-tailed towhee. The greatest number of individuals and species of bees occurred in upland sagebrush; this may be related to the variety of insect-pollinated flowering plants present.

In comparison with the other vegetation types, mixed brush had a moderately small mammal population. Least chipmunk and deer mouse were the commonly captured species but no small mammal species were captured only in this habitat. The green-tailed towhee was a common breeding bird while the dark-eyed junco and gray-headed junco were common birds in mixed brush during migratory periods. Mixed brush also provided browse for mule deer.

Some of the other vegetation types in the study area also had interesting characteristics, but due to their limited extent, their overall importance was believed to be low.

No threatened or endangered plants or animals were observed on Tract C-a, but the greater sandhill crane, whooping crane, and peregrine falcon were seen in the study area during baseline studies. Because these species are not likely to nest in the area, Tract C-a and adjacent areas probably do not provide critical habitat for these species.

Although the habitats and associated fauna on Tract C-a are ecologically important, they are not unlike other portions of the Piceance basin. The Piceance basin supports several big game species (mule deer, elk). However, populations of big game species on Tract C-a are apparently not high. In relation to numbers in the Piceance basin, the only large mammals (excluding cattle) that might be considered abundant on or near Tract C-a were feral horses. The study area was relatively undisturbed, except in the valley bottoms where bottomland sagebrush had been manipulated to improve forage for livestock. The habitats on tract had generally not been disturbed, except by recreational use and by oil shale exploration activities.

Complex interrelationships between biotic components within the Tract C-a system were indicated by baseline studies. The baseline studies provided information which will help promote a better understanding of the structure and function of the system as oil shale development proceeds. This information should help biologists predict potential impacts which might result from oil shale development. Once these impacts have been identified, measures can be planned to minimize adverse impacts on terrestrial biota.

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SEC. 4

SECTION 4

PHYSICAL & BIOLOGICAL INTERACTIONS

SECTION IV - PHYSICAL AND BIOLOGICAL INTERACTIONS

PREFACE

The relationships among abiotic and biotic parameters on Tract C-a and vicinity were examined by use of an interactions matrix (see Attachment G-1, Section 2.5 RBOSP Progress Report 10 1977). Over 5,000 potential interactions were investigated. A couplet system was used to rate potential interactions. Values ranged from 1 to 5. The first value represented the ecological importance of the interaction. The second value represented the importance of the interaction in the Tract C-a study area. The Tract C-a value was based on RBOSP baseline data. Where appropriate and feasible, statistical analyses were used as the basis of the evaluation. In many cases, however, it was necessary to make value judgements (based on qualitative data) regarding the importance of the interactions or relationship.

Definitions of rating values were assigned as follows:

-First Value- Ecological Importance	-Second Value- Importance to Tract C-a System
1-None/not applicable	1-None/not applicable
2-Slightly important	2-Slightly important
3-Moderately important	3-Moderately important
4-Very important	4-Very important
5-Extremely important	5-Extremely important

Judgements of ecological importance (first value) were based on a knowledge of semi-arid ecosystems, the literature, and the application of well-know ecological principles. Judgements of the importance of an interaction to Tract C-a (second value) were based on qualitative and quantitative baseline data and on the interpretations of experts who studied the system in detail during baseline studies. Information presented in the previous sections of this

report was used extensively to identify and evaluate the potential interactions among physical and biological parameters. Evaluation of interactions was accomplished by rating the influence of one parameter on another parameter using knowledge gained through baseline studies. When available, quantitative assessments were used to arrive at the rating value. In many instances, qualitative data and expert judgement were used to establish values since quantitative data were not always available.

Criteria for assignment of importance values were as follows:

Ecological Importance

- Direct relationships were ranked 4 or 5, less obvious relationships ranked 2 to 3.
- Well-known interactions (as reported in the literature) were ranked 4 or 5, less well-established interactions were ranked lower (2 to 3).
- Interactions specific to semi-arid ecosystems (such as Tract C-a) were ranked 3 to 5, more general interactions ranked 2.
- Interactions known for similar altitudes were ranked 3 to 5, those for less similar areas ranked lower.
- No relationship were ranked 1.

Importance to Tract C-a

- Relationships demonstrated or substantiated by quantitative baseline data were ranked high or very high (4 or 5).
- Relationships demonstrated or substantiated by qualitative baseline data were ranked moderately high (3 or 4).
- Relationships judged to be important by experts familar with the area and substantiated by specific baseline data ranked moderately high (3 or 4).
- Relationships judged to be important by experts, but not substantiated by specific baseline data ranked moderately high to low (3 or 2).
- No relationship were ranked 1.

Once the matrix importance value assignments had been completed for each of the potential interactions or relationships, all couplets of 4/4 or higher were circled and defined as "high level". Couplets between 3/2 and 4/3 were circled and defined as "moderate-level". All couplets between 2/1 and 2/2 were defined as "low-level" relationships 1/1 couplets represent parameters with no known interactions.

The following discussion presents some of the major relationships identified for the study area through this matrix analysis. High-level relationships are diagrammatically represented and discussed in detail. Selected moderate-level relationships are discussed briefly. Spatial limitations prohibit in-depth deiscussion of all moderate and low-level relationships. Readers desiring additional information regarding these relationships should consult the interactions matrix on file with the AOSS in Grand Junction, Colorado.

CHAPTER 1 - ABIOTIC ABIOTIC RELATIONSHIPS

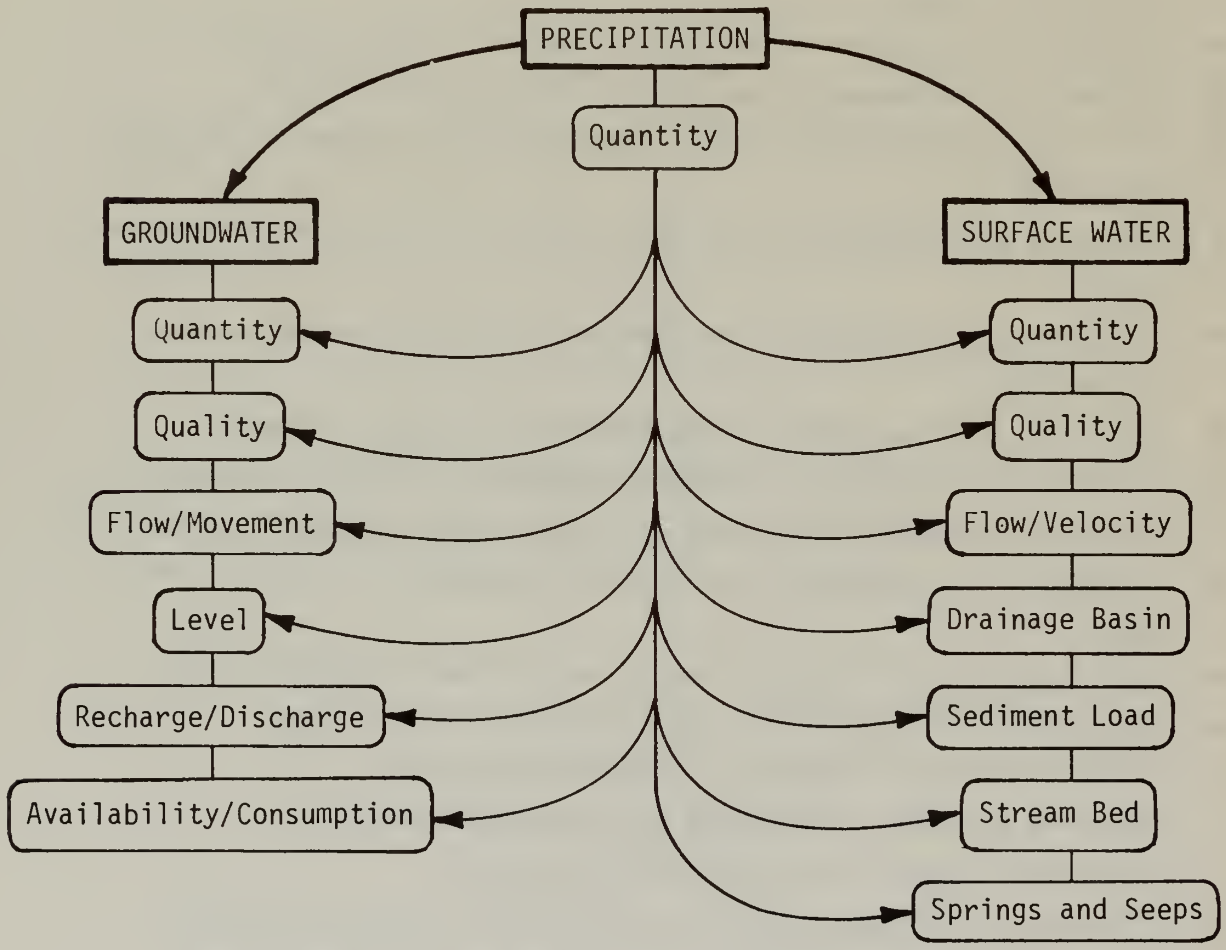
Influences of abiotic parameters on other abiotic parameters, that were rated as high-level relationships (4/4 or higher) included:

- Influence of precipitation (quantity) on groundwater (quality, quantity, flow/movement, level, recharge/discharge, availability).
- Influence of precipitation (quantity) on surface water (quality, quantity, flow/velocity, drainage basin, sediment load, stream bed, springs and seeps).
- Influence of groundwater quantity on surface water quantity.
- Influence of groundwater quality on surface water quality.
- Influence of groundwater quantity on quantity of water in springs and seeps.
- Influence of groundwater quality on quality of water in springs and seeps.
- Influence of groundwater flow/movement on surface water quantity and quality.
- Influence of groundwater flow/movement on springs and seeps.
- Influence of groundwater recharge/discharge on springs and seeps .
- Influence of groundwater level on surface water quantity and quality
- Influence of groundwater availability/consumption on springs and seeps.
- Influence of surface water flow on surface water sediment load.
- Influence of soil erosion on surface water sediment load.
- Influence of soil chemistry on sediment chemistry.
- Influence of slope on drainage basin characteristics.
- Influence of slope on soil erosion potential.
- Influence of drainage basin on surface water flow and velocity.
- Influence of terrain stability on surface water sediment load.

The influence of snowmelt on surface water flows on the tract in spring has been statistically demonstrated by baseline hydrology studies (see pages II-5 through II-33 of this report). One major source of stream flow on

tract is snowmelt runoff which typically begins in late Winter (February) to early Spring (April). Infrequent, but heavy, Spring thunderstorms also contribute to the availability of surface water. Effects of rain and snowfall on surface and groundwater have been measured during baseline studies. They include increased ground and surface water flows, changes in chemical concentractions and sediment loads following a precipitation event, higher water levels and erosion of the drainage basin and stream bed.

The influence of precipitation on ground and surface water can be diagrammatically represented as follows:

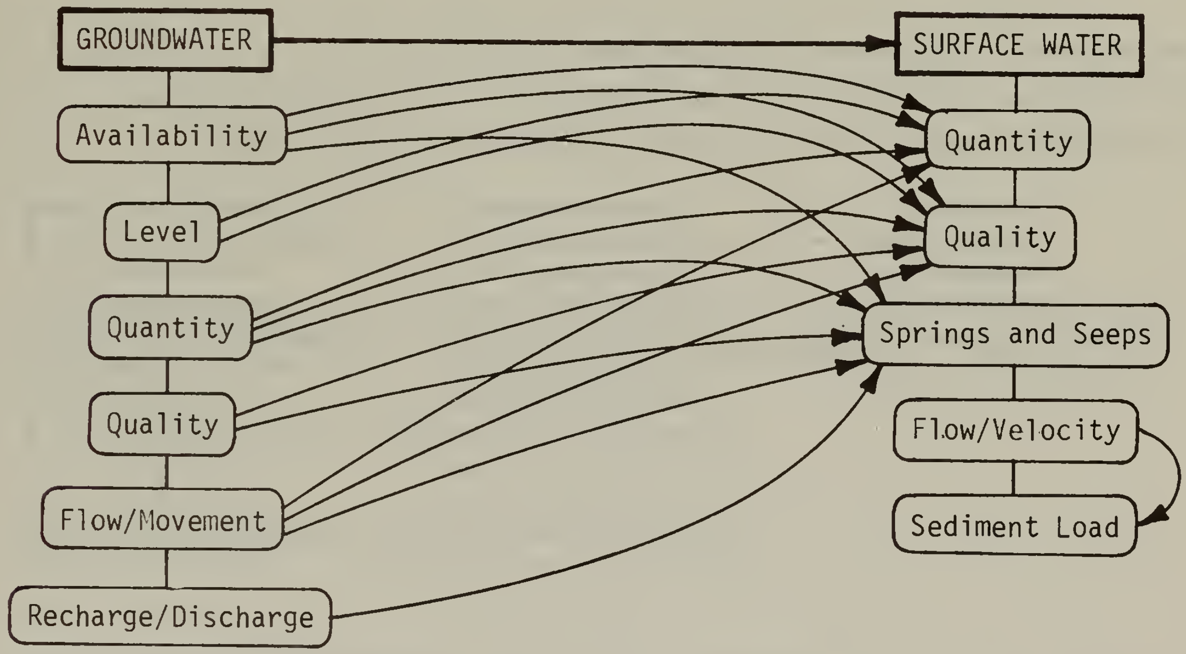


The influence of groundwater on the quantity and quality of surface water (especially springs and seeps and Yellow Creek) has also been demonstrated

by baseline hydrology studies (Section II). The data indicate that groundwater significantly affects the quantity and quality of surface water on tract.

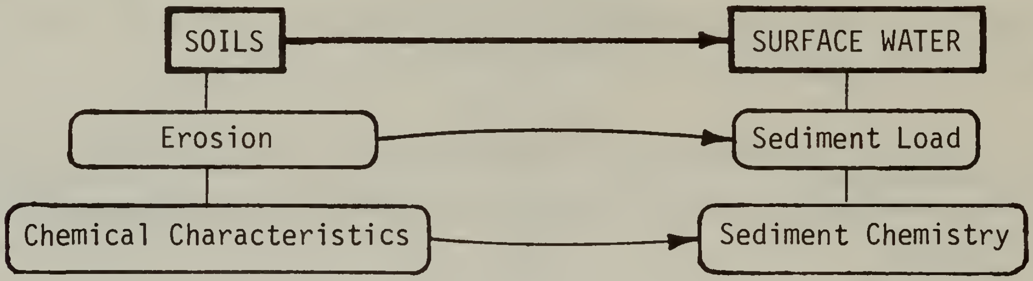
Most of the springs in the Tract C-a area are fed by alluvial or shallow bedrock aquifers. Parts of Corral Gulch, Box Elder, Stakes Springs, and Yellow Creek are fed by groundwater discharge, but other stream flows result from snowmelt runoff (Section II, Chapter 1). The quality of the surface water resource reflects its origin. The effect of groundwater on springs and seeps has been further demonstrated by hydrologic modeling studies which show a definite connection between the upper aquifer and many of the springs and seeps in the area.

Specific high-level relationships (4/4 or above) of groundwater on surface water and between surface water parameters on Tract C-a are diagrammatically presented below:

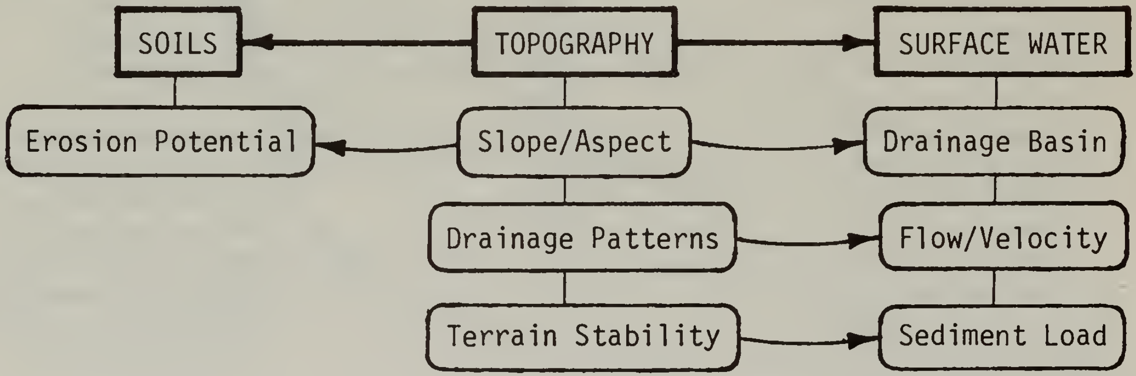


The relationship between surface water flow and surface water sediment load on Tract C-a showed a significant positive correlation (at the 95 percent confidence level) (Table 2.8, Section II).

The relationship of soil erosion potential and surface water sediment load and sediment chemistry are more difficult to quantify. Baseline data indicated that soils in the study area are moderately to highly erodable. This results from several factors, including ground cover (Section III, Chapter 4). An increase in turbidity and sediment load during periods of high runoff has been observed during baseline aquatic studies. Baseline data further indicate that sediment chemistry generally reflects adjacent soil chemistry. Variability in the data and limited replication, however, preclude the determination of possible statistical correlations between these parameters. High-level relationships are shown below:



The influence of topography (slope, terrain stability) on the drainage basin and soil erosion and related effects of the drainage basin on surface water flows reflect physical influences as shown below:



Less pronounced, but nevertheless important, relationships (moderate level) occur among a number of abiotic parameters (see interactions matrix, RBOSP Progress Report 10 1977). Several of these are listed below.

- Influence of particulate concentration on visibility
- Influence of precipitation on particulate concentration
- Influence of soil erosion on particulate concentration
- Influence of ambient air temperature on relative humidity
- Influence of precipitation on visibility

Roadways are the common source of fugitive dust which frequently reduce visibility appreciably. Baseline data analyses have shown significant positive correlations between high wind speeds and particulate concentrations (RBOSP DDP 1976). Heavy traffic (during hunting seasons) also contributes to particulate concentrations. The largest variation in overall mean visibility occurred along the path which lies across Piceance Creek basin. This may result from the entrapment of atmospheric suspended particulates in the basin until the basin air movement is sufficient to clear away the trapped material (Section I, Chapter 6).

The occasional relief from fugitive dust in the study area is usually accompanied by a precipitation event which wests the substrate. Particulate levels are generally higher in areas of erodable soils (e.g., roads, drill pads). Factors which affect this relationship include wind, plant cover, and surface disturbance.

Visibility studies in the area have demonstrated that haze or storm clouds are occasionally responsible for reduced visibility (Section I, Chapter 6).

CHAPTER 2 - ABIOTIC-BIOTIC RELATIONSHIPS

Nine abiotic-biotic relationships in the tract C-a area were ranked as high-level (4/4 or above):

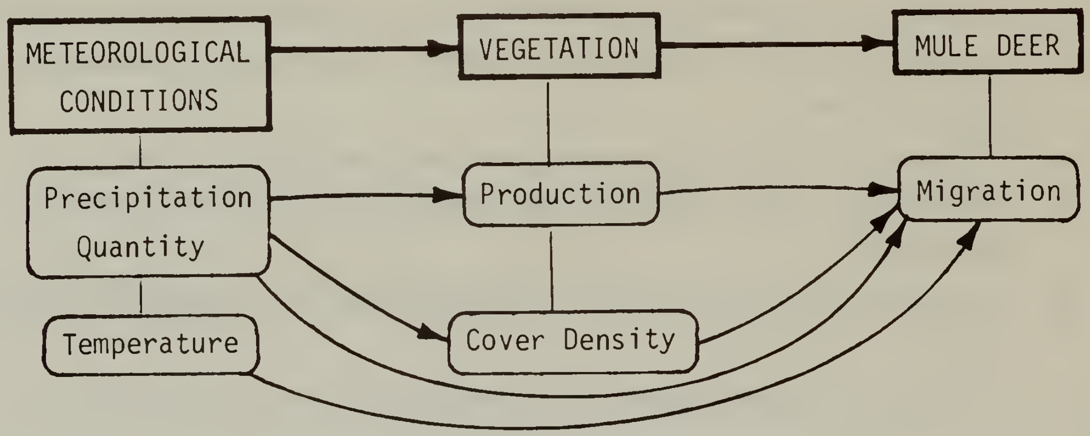
- Influence of precipitation quantity on vegetation production
- Influence of precipitation quantity on vegetation cover and density
- Influence of precipitation quantity on mule deer migrations
- Influence of ambient air temperature on large mammal migrations
- Influence of soil chemical characteristics on plant community distribution
- Influence of soil trace metals on trace metals in plants
- Influence of soil chemical characteristics on plant community composition
- Influence of soil physical characteristics (e.g. depth) on plant cover
- Influence of slope/aspect on vegetation cover or composition

Aspects of the climatic regime of critical importance to plants in the Tract C-a study area are distribution and amount of rainfall and snowfall, length of the growing season, maximum and minimum temperatures, and the frequency and velocity of wind (RBOSP Progress Report 10 1977, Terrestrial Section, p. 15). Of these, the influence of precipitation are most readily discernable. The baseline quantities of precipitation on Tract C-a are believed to reflect short-term drought conditions rather than long-term climatic conditions (Section I, Chapter 2).

These drought conditions have probably resulted in decreased production, cover, and density of vegetation. Spearman rank correlations between percent herbaceous cover and cumulative precipitation for six vegetation types over two years revealed a significant correlation (at P = .05 level) on Tract C-a (Section III, Chapter 3). Cover within individual vegetation types was not significantly correlated with percent cover except for shadscale (P = .05 level).

The influence of precipitation (as snow) on mule deer was not quantified for Tract C-a. However, studies of mule deer herd movements by the CDOW indicate that migrations are affected by temperature drops and increasing snow depths (Loveless 1967). Gilbert et al.(1970) found that snow depths in excess of 18 inches appreciably affected deer use of winter range in Middle Park, Colorado.

Potential high-level relationships among precipitation, vegetation and mule deer are depicted below:



Analysis of baseline data failed to reveal significant correlations (at $P = .05$ level) between chemical soil traits and plant cover (Section III, Chapter 1). However, some constituents are believed to be important, even though no significant correlations were demonstrated.

The distribution of plants is effected by chemical and physical traits of soils throughout the study area. Greasewood is limited to highly saline, sodic and strongly alkaline soils in alluvial bottoms (Section III, Chapter 1). Pinyon-juniper stands occur on shallow soils at low and intermediate elevations, big sagebrush occurs in thicker alluvial deposits and on gently sloping uplands with relatively deep soils; and bald areas occur on shallow soils of upland areas. Spearman rank correlation analysis revealed that there is a significant positive correlation (at $P = .05$ level) between soil depth and herbaceous cover in the six combined vegetation types (Section III, Chapter 3).

Some soil constituents increase while others decrease in value as a function of soil depth, but in general there are only a few significant correlations between soil depth and changes in chemical properties. Salinity, pH, and exchangeable sodium percentage significantly increased with depth. Trace element concentrations were generally constant throughout the surface and subsurface soil profiles.

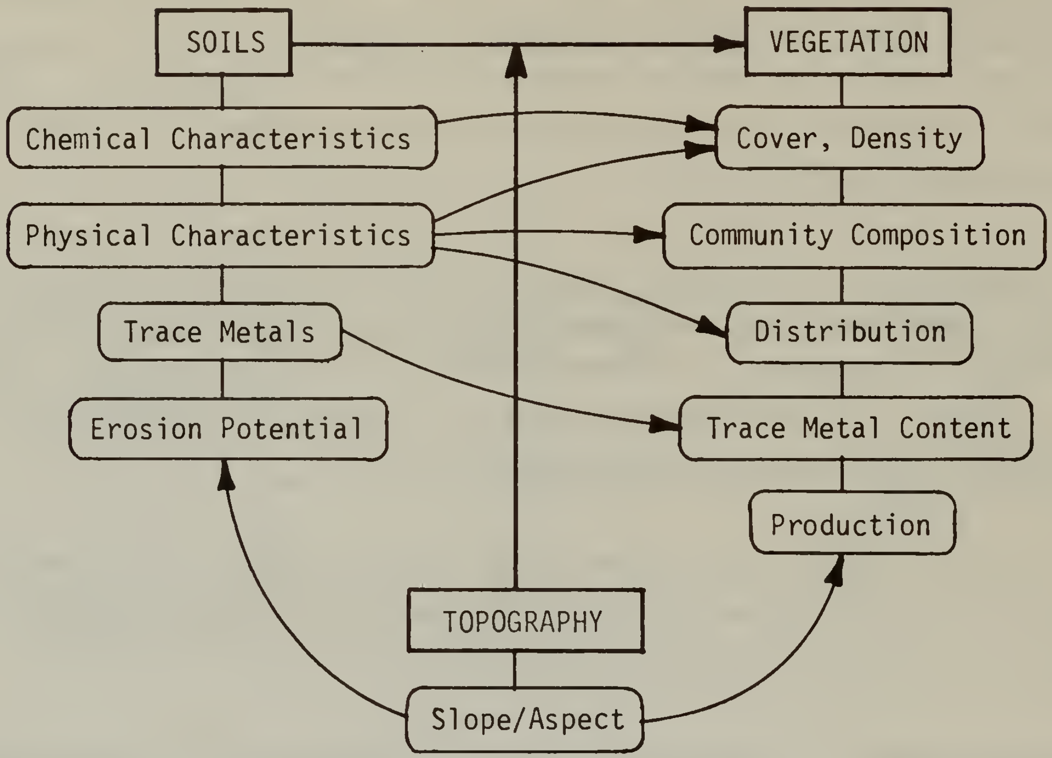
The association of a particular type of vegetation with particular soil constituents does not necessarily mean that the vegetation imparted these traits to the soil. Differences in parent material, relief, microclimate, and time influence soil traits and may mask the influence of vegetation or erroneously imply vegetative influence.

Trace metals in soils can be taken up by plants. Levels of trace metals in Tract C-a soils are generally within expected ranges for arid ecosystems (Section III, Chapter 1).

Geological deposits in the study area greatly influence soil types present. Physical properties (structure and texture) of soils determine aeration and moisture-holding capacity, and soil depth is an important factor in regulating moisture availability to plants. Depth to the water table affects the distribution of plant species, particularly along alluvial stream bottoms (RBOSP Progress Report 10, Terrestrial Section, p. 17).

Variations in topography affect the amount of sunlight striking different slopes. The steepness of slope affects the angle of incidence and the direction of slope affects the duration of sunshine on the slope. The Tract C-a vegetation map (Section III, Chapter 4) illustrates the coincidence of vegetation type boundaries with abrupt changes in topography, such as between north - and south-facing slopes on ridges which divide drainages (RBOSP Progress Report 10 1977, Terrestrial Section p. 5).

A diagrammatic presentation of these major interactions is shown below:



Moderate-level relationships of the abiotic system on biotic components are varied. They include as examples:

- Influence of seasonal ambient air temperature on vegetation production, and distribution of small mammals (e.g. hibernation, estivation)
- Influence of ambient air temperature on distribution of large mammals
- Influence of ambient air temperature on herptofauna and avifauna distribution
- Influence of surface water quantity on vegetation (productivity, distribution, and cover)
- Influence of surface water quantity on amphibian relative abundance, and distribution

- Influence of surface water quantity on aquatic biotic communities
- Influence of soil erosion on vegetation
- Influence of soil erosion on aquatic habitats
- Influence of stream substrate type on aquatic biotic communities
- Influence of stream velocity on aquatic biotic communities

Many of these relationships are closely linked with previously discussed high-level relationships.

Periods of greatest biological activity were recorded during warm seasons. Vegetative production (and cover) increased in Spring and early Summer and decreased in mid-Summer (see phenology data, pp. 19-57, RBOSP Progress Report 10, 1977, Terrestrial Section). By fall, vegetation production on Tract C-a has fallen sharply, and most perennial plants have become dormant.

Seasonal weather changes influence changes in the small mammal populations. Many species become quiescent during cold weather--others during extreme heat of summer periods. Baseline data showed that small mammal numbers were low in the spring, higher during the summer and quite low during the winter (pp. III-116).

The response of mule deer to dropping winter temperatures (and snowfall) has already been mentioned. Their response to less harsh weather conditions has been demonstrated by over-wintering populations in the Piceance Creek basin during mild winters (pp. III-120 to 131).

Surface water sources contributed appreciably to terrestrial habitat diversity. Riparian habitats or similar areas (e.g., emergent vegetation) are scarce in the study area. Those that do occur support faunal species not otherwise found in the study area (e.g., amphibians) and a much greater diversity of fauna than other terrestrial habitats (RBOSP Progress Report 10, 1977, Terrestrial Section). The total vegetative cover in these areas was relatively high (50 to 80 percent) and vegetation species composition more diverse than

in other areas. Availability of surface water is the primary determinant of the occurrence and extent of this habitat type(RBOSP Progress Report 10, 1977, Terrestrial Section pp. 50-51.

The limited availability of surface water on Tract C-a severely limits the extent and characteristics of aquatic habitat for the area (Section II, Chapter 4). The biotic communities supported by these limited water sources are composed of those species which are adapted to ephemeral stream flows and water quality characteristic of the area.

Erosion and loss of surface soil affects vegetation in the study area, since vegetation has difficulty in becoming established in highly eroded areas.

The increase in stream sediment load with increased erosion and stream flow has already been discussed in some detail. The effect of this phenomenon on aquatic habitat is related to the direct effect of sediment load on aquatic organisms. Baseline data have shown that aquatic species in the study area are those which are well adapted to the chemical and physical conditions of the Tract C-a environment (Section II, Chapter 4).

CHAPTER 3 - BIOTIC-ABIOTIC RELATIONSHIPS

The number of important influences on the abiotic system by biotic components is limited (see interactions matrix, RBOSP Progress Report 10 1977). Only one such relationship--the effect of plant cover and density on soil erosion potential was rated as high potential relationship. Moderate-level relationships identified included:

- Influence of vegetation (distribution and cover) on atmospheric particulate levels
- Influence of plant community composition soil chemical characteristics
- Influence of invertebrate relative abundance on soils (erosion potential, physical and chemical characteristics)
- Influence of vegetation cover on soil erosion potential

The distribution and density of vegetation in a given area affect the distribution and concentration of wind blown particulates. Areas with limited ground cover are subject to higher particulate (fugitive dust) concentrations than areas which support relatively dense ground cover.

The composition of plant communities can affect soil erosion to varying extents. Pinyon-juniper communities in the tract area often exhibited limited ground (understory) cover and, therefore, high erosion hazard. The reasons for this limited understory vary (e.g. allelopathic responses to plant toxins produced by junipers), but lack of ground cover appears to be closely related to high erosion rates (Section III, Chapter 4, pp. III-92).

Vegetation plays a role in the redistribution of soil constituents and the contribution of organic humus. Different types of vegetation are known to impart different characteristics to the soil substrate (Section III, Chapter 1). There is some indication that certain plant communities in the tract area (e.g. shadscale) have affected the adjacent soil chemistry (Section III, Chapter 1).

The relatively large numbers of harvester ant colonies in the tract area may have contributed to changes in soil traits such as erosion potential, physical texture and chemical composition and distribution as well as plant species distribution and abundance.

From the evaluation of relationships among biotic parameters, two distinct clusters were apparent (see interactions matrix in RBOSP Progress Report 10). One cluster occurred in the area of upper left hand portion of the matrix where the effects of terrestrial parameters on other terrestrial parameters were concentrated. The second cluster was formed among the potential relationships in aquatic communities. Interactions between the two systems were limited to a few moderate- and low-level relationships.

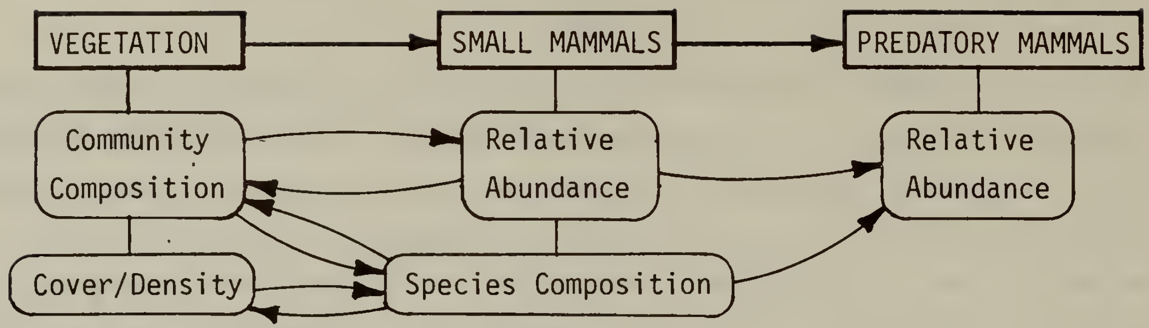
Relationships within each system which were ranked as high-level included the influence of:

- Vegetation community composition and cover on small mammal abundance
- Small mammal relative abundance on the relative abundance of predatory mammals
- Vegetation production on mule deer migrations
- Vegetation cover on mule deer migrations
- Periphyton abundance on periphyton productivity and on benthos relative abundance.

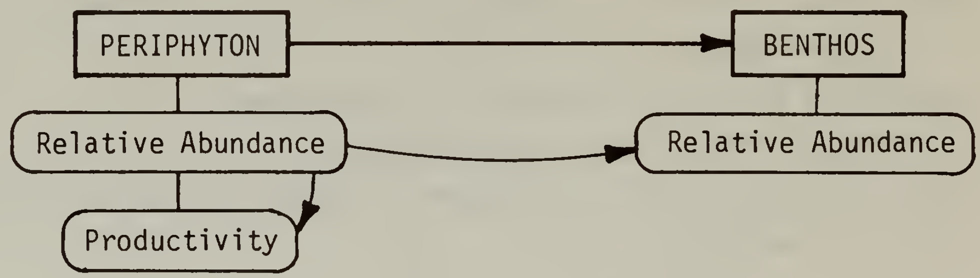
The vegetative community composition and cover of plants in the Tract C-a ecosystem may affect numbers of small mammals present, especially seed-eaters. Increased cover provides favorable habitat for certain small mammal species and could contribute to increased abundance. Microhabitat affinity determinations for small mammals in the tract area indicate that cover is of primary importance to small mammal populations (Section III, Chapter 5).

Increases in small mammal population numbers are commonly followed by apparent increases in predator populations (i.e. coyotes, bobcats).

Interactions judged to be high-level can be illustrated as follows:



The influence of periphyton abundance on productivity of aquatic ecosystems on Tract C-a is related to its role as the major primary producer in the system (Section II, Chapter 7). Benthic organisms in the tract area are heavily dependent on periphyton as a food source. Baseline data indicate that benthic abundance was highest in aquatic habitats which supported high algal biomass (p. II-307). These relationships can be depicted thusly:



Moderate-level relationships among biotic components include influence of:

- Vegetation production on small mammal populations
- Vegetation production on large mammal populations
- Vegetation community composition on faunal constituents
- Vegetation condition on distribution and movement of large mammals
- Small mammal abundance on vegetation condition
- Small mammal abundance on small mammal distribution
- Small mammal abundance and distribution on predatory mammal abundance and distribution

- Large mammal relative abundance on vegetation condition
- Periphyton on plankton
- Benthos on periphyton
- Fishes on benthos

Most of these interactions are qualitatively substantiated by baseline data. For qualifying data, consult previous sections of this report. For a more complete listing of Tract C-a interactions, examine the interaction matrix on file with the AOSS in Grand Junction, Colorado.

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SEC. 5

SECTION 5

CULTURAL RESOURCES

SECTION V - CULTURAL RESOURCES

PREFACE

During the two-year RBOSP baseline study period, intensive cultural resource surveys were conducted on Tract C-a and vicinity. The overall purpose of these surveys were to inventory and evaluate cultural resources of the project area; to establish which locations should be considered for more intensive archaeological, historical, or paleontological investigation; and to determine if any cultural sites were eligible for nomination to the National Register of Historic Places in compliance with criteria set forth in the Federal Register, Vol. 41(82), 27 April 1976, pursuant to E.O. 11593. Attendant to these objectives, the cultural resource survey was carried out in four phases:

- An archaeologist from the University of Denver, Dr. Alan Olson, was contracted to conduct an intensive area-wide search to locate and inventory cultural resource materials in the study area. He was further requested to thoroughly evaluate all archaelogic materials recovered from the survey area in terms of their importance for nomination to the National Register of Historic Places.
- A historical archaeologist, Mr. Steven Baker, was contracted to visit the study area and evaluate all historic sites identified by Dr. Olson and others and to attempt to locate and evaluate other sites which were, in his opinion, of potential historic significance.
- A paleontologist, Dr. Paul O. McGrew, University of Wyoming, was asked to examine and evaluate paleontological materials recovered from the area and offer an opinion regarding the importance of the area for paleontological purposes.
- Information and recommendations supplied by all three of these scientists were incorporated into a Cultural Resources Survey

Report (RBOSP 1976) and recommendations regarding significance of cultural resource sites identified during the survey to the National Register of Historic Places were made.

Searches of the literature were conducted in each discipline and both historic and archaeologic state site files were examined. Listings on the National Register of Historic Places were studied and other scientists known to have surveyed the area were contacted, as well as state and federal agency personnel.

In October 1976, RBOSP published a Cultural Resources Survey report (RBOSP 1976) which integrated results of all three disciplines in an attempt to present a complete description of the cultural and paleontological resources of the study area. The current report is a summarization of the 1976 report.

The cultural resources inventory conducted by RBOSP was performed in compliance with stipulations set forth in Tract C-a Oil Shale Lease Environmental Stipulations and References (U.S. Dept. Interior, Bureau of Land Management), the Antiquities Act of 1906, the National Historic Preservation Act of 1966 (as defined in 36 CIR 800), the National Environmental Policy Act of 1969, the Archaeological and Historic Preservation Act of 1974, Executive Order 11593 of 1971, 40 CFR Part 1500 - Guidelines for the Preparation of Environmental Impact Statements, the Colorado State Antiquities Act of 1973, and the Colorado Land Use Act of 1974.

CHAPTER 1 - ARCHAEOLOGICAL RESOURCES

ABSTRACT

An intensive (100 percent) archaeological survey was conducted on Tract C-a and neighboring vicinities during the two-year base-line period. During these studies, 196 archaeological sites, mostly lithic scatters, were identified. Prior to the RBOSP survey a 1973 Survey funded by Thorne Ecological Institute and Colorado State University had revealed the presence of several additional sites.

Evidence gathered indicates that the area represents four periods of utilization: Archaic (7,000-6,000 B.C.), Fremont (500 A.D. -?) Ute (?),and 19th Century Anglos (1800's-present). In addition, the possible discovery of an extremely old Paleo Indian projectile point may mean that the area was occupied much earlier than previously expected.

The objectives of the archaeological survey conducted on Tract C-a were to: inventory and evaluate all archaeological resources in the area; to establish the need, if any, for additional studies, and to determine if any sites in the area were worthly of nomination to the National Register of Historic Places

ARCHAEOLOGY

A 100 percent survey of Tract C-a and 84 Mesa, and opportunistic investigations of areas outside these boundaries led to the discovery of 196 archaeological sites. A large variety of artifacts was recovered including four basic types of projectile points, and a variety of chipped stone tool materials including hammerstones, drills, blades, scrappers, gravers, cores and associated debitage. Metates, manos, potsherds, pottery fragments, and colored beads were also recovered from the study area. At six locations remains of Ute wickiups were discovered. Complete descriptions of artifacts recovered from all 196

sites is given in the Cultural Resource Survey Report (RBOSP 1976).

Sites at which these artifacts were found were described as either primary, secondary or tertiary, based on the amount of tool material found or the potential of revealing a significant archaeological contribution. Primary sites generally yielded moderate to large amounts of tools and/or wastage or housed wickiup structures. Secondary sites yielded less material, but still provided important information. Teriary sites were usually limited to a few waste chips which provided little additional information on the archaeological resources of the area.

Evaluation of the archoeological significance of the area was accomplished by analysis of:

- Individual sites in regard to amount and type of material found in the area.
- Lithic stone tools and fragments recovered from the area in relation to material used, method of manufacture, use, and location of manufacture.
- Projectile points recovered from the area and classification by size, shape, method of manufacture and material used.
- Relationship among the various sites to determine extended or repeated periods of use and potential for discovery of subsurface material.

This evaluation revealed that 14 of the 196 sites located were primary sites, 47 were secondary sites and 135 were tertiary sites. No primary and only one secondary site were found on Tract C-a during the RBOSP Survey. However, Jennings (1974) found one site in the southeast cornor of Tract C-a that would, because of the unusual and significant find there, have been classified as a primary site if this classification scheme had been used.

Jennings (1974) found what he believed to be the basal fragment of a Paleo Indian projectile point (site 5RB13). In addition he found debitage of similar material at the site. If this site actually supports Paleo Indian artifacts,

it could represent one of the oldest archaeological findings in the state. Maps showing locations of all sites found during the survey appears in the Cultural Resources Survey report (RBOSP 1976)

Ten types of lithic stone tools were recovered from the study area including: projectile points, knives, scrappers, drills, gravers, choppers, utilized flakes, cores, hammerstones, and ground stone tools. A total of 2,925 individual artifacts was recovered from primary and secondary sites alone. Only 365 items were classified as tools. The remaining 2,560 items were tabulated as waste flakes. Projectile points made up most of the lithic tools (26 percent), followed by knives (24 percent), scrappers (24 percent), and utilized flakes (21 percent). Analysis of toolstone used for these tools revealed that the chipped stone tool material does not occur as natural deposits within the study area. Therefore, this material had to be transported into the area by man. Further examination of ratio of waste flakes to finished tools and occurrence of cores and rinds indicated that the majority of the toolstone imported into the area had already been partially fashioned elsewhere.

Projectile point analysis was carried out on the 143 projectile points recovered from the area. Of this total, 60 were identifiable and could be classified as one of the four following types:

- Type 1 - unnotched, possibley Fremont culture
- Type 2 - side-notched, late Fremont or early Shoshonean
- Type 3 - corner notched, possibly 6,400 B.C.
- Type 4 - corner notched, not as heavy as Type 3, possibly 6,000 B.C. or Fremont through Shoshonean period.

Twenty-one Type 1, nineteen Type 2, three Type 3 and seventeen Type 4 points were identified. Complete descriptions and photographs of these artifacts appear in the Cultural Resources Survey report (RBOSP 1976).

Areal extent and proximity of sites to other sites was also examined to shed further light on the extended or repeated use of the area by early man.

This examination revealed the possible presence of four clusters of sites. These clusters tend to indicate that similar settlement patterns were followed in the area over a number of centuries, and extended through Archaic, Fremont and Ute periods. These areas were probably used repeatedly for short periods of time when hunting and/or gathering was successful.

CONCLUSIONS

The combination of hunting tools, meat and skin processing tools, and tools used for the preparation of vegetal materials recovered from the study area suggest that the area was occupied during late summer and fall. A limited food supply during some seasons probably prevented large gatherings of people. The types of tools suggest that two patterns of exploitation, interlocked in terms of time, occurred in the area. In late summer and fall, hunting and gathering could have been practiced simultaneously. Hunting was probably performed by men and gathering by women and children except during highly successful seasons when processing of game and gathering may have been shared. The area was primarily used as a source of game and vegetal products. Agriculture was probably not practiced in the basin except in lowland areas to the north and east along the major drainages.

Field and laboratory analysis indicate there were at least four periods of occupation of the area; an Archaic period perhaps beginning as early as 7000 to 6000 B.C.; followed by the Fremont Culture that began after 500 A.D.1 the Ute, whose beginnings are not presently established; and, finally, the 19th Century Anglos.

The socio-political organization of early man in the area (Archaic) was probably uncomplicated. Exploitation was accomplished most efficiently by the extended family unit. They must have possessed considerable knowledge of natural history, seasonal patterns of game movements, and ripening times of various plants, as these were the criteria that would have dictated the movement of the group. Exploitation patterns indicate that deer, elk, plants,

fish, insects, waterfowl, rodents and reptiles were eaten. Material culture was geared to frequent changes in location. Flexible containers of hide or basketry were used instead of ceramics. Other types of equipment were practical and portable. Clothing was minimal, and housing constructed only when a subsistence item was plentiful enough to support the group in one place for a period of time. Caves or overhangs were used when they occurred. Most Archaic artifacts found in the area were projectile points. This occupation could have extended back several thousand years, but this cannot be positively confirmed from limited surface materials recovered during the survey.

As the Archaic pattern faded, it was replaced by the Fremont Culture. In general, this transition involved expansion of agricultural practices and use of pottery. However, evidence for Tract C-a deems it unlikely that agriculture was practiced in the immediate vicinity. Artifacts of the Fremont era are more refined than from the Archaic period. Projectile points are smaller and shaped differently.

Introduction of the Ute culture (as indicated by presence of wickiups) into the area cannot be postively pinned down. It may have occurred as an extension of the Fremont period with the advancement of use of horses and European goods.

The possible discovery of a fragment from a Paleo Indian projectile point could mean that man was utilizing the area at a much earlier date than previously expected. For these reasons, it is concluded that additional studies of major site clusters and site 5RB13 could be useful in establishing pre-historic use of the Piceance Creek basin.

Results of the Cultural Resource Survey indicate that Site Cluster II and site 5RB13 might be worthy of nomination to the National Register of Historic Places.

CHAPTER 2-HISTORIC RESOURCES

ABSTRACT

Fifteen historic sites were identified within the vicinity of Tract C-a. Ten of these sites were classified as homesteads, either cabins, ranches or residences. One site was a school and four sites were locations of horse traps.

Historic development of the area falls into three periods. An early homesteading period began around 1885 and continued through 1895. This was followed by about 20 years of insignificant activity before the second homesteading period began around 1918. Homesteading continued until the 1930's or the depression. The most recent use of the area has been for running cattle and trapping of wild horses. Horse traps in the area date from the 1950's to the near present.

Basic objectives of the historical survey were to determine if any historic sites on the study area were likely to yield information on the historical development of the area and whether any were worthly of further study or nomination to the National Register of Historic Places.

HISTORY

The primary historical factor leading to the settlement of the study area by Euro Americans appears to have been the cattle industry. Sheep have never been brought to the area, there is no evidence that dry land farming was practiced, and there is no mining industry prior to the current speculation in oil shale.

Utilization of the area by Euro Americans apparently falls into three periods:

- Period I - Initial Homesteading (ca. 1885-1895)
- Period II - Second Homesteading (ca. 1918-1930)
- Period III - Residual Exploitation (ca. 1950-)

The first period is represented in the study area by three homestead sites, including 84 Ranch. Homesteading during this period apparently resulted from man's attempt to utilize even marginal grazing lands for the production of cattle as land became increasingly scarce. These homesteads were apparently occupied for only a short while. Complete descriptions of these homesteads appear in the RBOSP Cultural Resource Survey report (1976).

Period II is represented by seven homestead sites and a school. This renewed homesteading period was probably generated by the passage of two new homestead acts - the "Enlarged Homestead Act of 1909" and the "Stock-Raising Homestead Act of 1916". Both these acts enlarged the sizes of permissible homestead plots in an effort to satisfy western cattle interests. The sites indicative of this period have outbuildings and other improvements which suggest more permanent occupation than during Period I. Use of 84 Ranch continued through this period, but other Period I homesteads were abandoned before Period II began. Both Period II homesteads and 84 Ranch were apparently abandoned prior to 1950, and the Great Depression of the 1930's.

Period III was marked by intermittent use of the area by cattle ranchers living outside the immediate vicinity. Previously abandoned homesteads were sometimes used as "cow camps" especially 84 Ranch. During this period wild horses were sometimes captured in horse traps constructed of pinyon-juniper limbs. Four of these horse traps remain in the area. Horse trapping probably continued until the passage of the Wild Horse and Burro Act of 1971 which made such activities illegal.

CONCLUSIONS

Historic utilization of the study area has been largely influenced by the cattle ranching industry. The limited number of homesteads in the area were occupied for brief periods of time (a few months to a few years) and were abandoned as the range became less productive. None of the sites in the study area can contribute significantly to Colorado's history. Results of this survey indicate that none of the historic sites identified in the study area are of National Historic Register significance.

CHAPTER 3- PALEONTOLOGICAL RESOURCES

ABSTRACT

Material of probable paleontological origin were recovered from nine sites in the study area. These various materials were identified as fossil fragments of a uintathere vertebra, a turtle carapace, unidentified mammal bone (probably Eocene), pertified wood, and non-fossilized deer or bison bone.

The objectives of the paleontological resource survey were to inventory paleontological materials recovered from the study area to determine if there was any potential for significant paleontological finds and to evaluate sites regarding the possibility of future discoveries. Significant was defined as paleontologically unique to the area or as an unusually large concentration of well-preserved fossils.

PALEONTOLOGY

Paleo-finds were examined from nine sites in the vicinity of Tract C-a. These finds included fossil fragments of a uintathere vertebra, a turtle carapace, and a mammal from the Eocene period; fragments of pertrified wood, period not identifiable; and non-fossilized deer or bison bone.

All of these finds are common to the Piceance Creek basin and as such do not represent significant paleo-finds. In addition these finds were found lying loose and could have been transported into the area by early man.

CONCLUSION

None of the paleontological sites are considered significant and no recommendation for further study based on the current evidence is warrented.

CHAPTER 4 - SIGNIFICANCE OF AREA'S CULTURAL RESOURCES

Intensive studies of archaeologic, historic and paleontologic resources of Tract C-a and vicinity have revealed that the area is not particularily well-endowed with cultural materials. A reasonably large number of lithic artifacts were located during the survey, but by far the majority of these were merely waste flakes or debitage from tool making. None of the artifacts recovered could be dated, therefore, estimates of pre-history occupation must be based on tool types and shapes as compared with similar artifacts recovered from other areas were dating is possible.

Historic use of the area has been sparse, represented by a few briefly occupied homesteads which have now all been abandoned. Historic use has been closely linked with cattle ranching which continues into the present.

None of the paleontologic materials found were of any significance in revealing additional information on the area.

The most significant aspect of the cultural resource survey has been to make available heretofore unavailable information on man's early utilization of the area. The large number of archaeologic sties discovered and the possible clustering of sites in certain areas points to the use of the area by early man over a period of years. Such extended occupation could mean that subsurface materials of even an older vintage could occur in the area. The additional find of a possible Paleo Indian point reinforces this possibility. Therefore, while the general area is not considered a major cultural resource find, the larger sites (primary and secondary) within Site Cluster II and the site of the Paleo Indian point find are considered worthly of protection in the event they could contribute to the history of Colorado. For this reason the BLM has recommended that these two areas be nominated to the National Register of Historic Places and has set up guidelines for the protection of these sites. This recommendation was made in a "Determination of Effect" received January 7, 1977 by the AOSS in compliance with Section 106/2b Procedures of E.O. 11593.

Recommendations for protection of these sites and other cultural resources in the proposed development area include:

"1. Site Cluster II shall be avoided whereever possible during the construction and operation phases of the proposed plan. Site Cluster II, located near 84 Mesa, will not be affected by most construction. The sites that may be affected shall be flagged and primary sites will be tested and salvaged by a qualified archeologist upon disturbance or treat of disturbance. All artifacts removed shall be mapped, recorded and then curated by an approved institution and/or laboratory. Site number 5 RB13, which is located on Tract C-a shall be tested and if necessary excavated by a qualified archeologist. All materials salvaged shall be mapped, recorded, photographed and curated by an approved institution or laboratory."

"2. The lessee shall immediately bring to the attention of the lessor, through the Mining Supervisor, any and all antiquities or other objects of historic or scientific interest including but not limited to historic or prehistoric ruins, fossils, or artifacts discovered as a result of operations under this lease and shall leave such discoveries intact until told to proceed by the mining supervisor. In cases where salvage excavation is necessary, the cost of such excavations shall be borne by the lessee."

LITERATURE CITED

Jennings, C. 1974. Impacts of the Oil Shale Industry upon archaeology and its history, Piceance Creek Basin, Rio Blanco and Garfield Counties, Colorado. Thorne Ecological Institute, Regional Oil Shale Study, Boulder, Colorado.

RBOSP, 1976. A cultural resources survey in Rio Blanco County, Colorado. Gulf Oil Corporation and Standard Oil Company (Indiana), Denver, Colorado 341 pp.

SEC. 6

SECTION 6

REVEGETATION

SECTION VI - REVEGETATION

PREFACE

In 1975, RBOSP initiated a three-year experimental revegetation program which will be used to evaluate those aspects of technology that are directly applicable to the reclamation planned for Tract C-a (RBOSP Detailed Development Plan, 1977).

In accordance with Section 11 of the lease stipulations, RBOSP will restore affected lands to a condition at least equal in quality to pre-existing land uses in the area and one that is compatible with adjacent undisturbed areas. Implementation of the revegetation program should insure that all land disturbed by RBOSP mining activities is restored to conditions that are at least as good as pre-disturbance conditions. The reestablished vegetation will be of a quality at least equal to that disturbed. The RBOSP experimental revegetation program will provide information specific to Tract C-a which can be used to evaluate the final reclamation plans.

The RBOSP experimental revegetation program includes three successive plantings (1975, 1976, and 1977). The first two plantings were made in the fall of 1975 and 1976. The schedule for the RBOSP studies is presented in Table 6.1 .

The locations of the first year experiments (Sites R_1 and R_2) and the second year experiments (Site R_3) are presented in Figure 6.1. All three sites are located in the southeast corner of the tract (T2S, R99N, Section 10) along Wolf Ridge, between elevations of 7,100 and 7,200 feet. Wolf Ridge is adjacent to Rinky Dink Gulch which is the planned disposal site for the processed shale during commercial operations. Sites R_1 and R_2 are located on opposite slopes (north and south) and R_3 is located on the south slope to further investigate the slope having the more extreme drought conditions.

TABLE 6.1

SCHEDULE OF FIELD EVENTS FOR REVEGETATION STUDIES ON OIL SHALE TRACT C-a, RIO BLANCO COUNTY, COLORADO, 1975 THROUGH 1978.

	1975						1976												1977												1978											
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Site Selection	Δ																																									
Field Work																																										
Seedbed Preparation				Δ												Δ												Δ														
Planting				Δ												Δ												Δ														
Measurements of Plant Response to Treatments												Δ		Δ										Δ		Δ										Δ		Δ				
Soil Analyses																																										
Sample Collection				Δ												Δ												Δ														
Moisture Determinations					Δ							Δ		Δ		Δ								Δ		Δ		Δ								Δ		Δ		Δ		
Salinity Determinations																Δ												Δ												Δ		

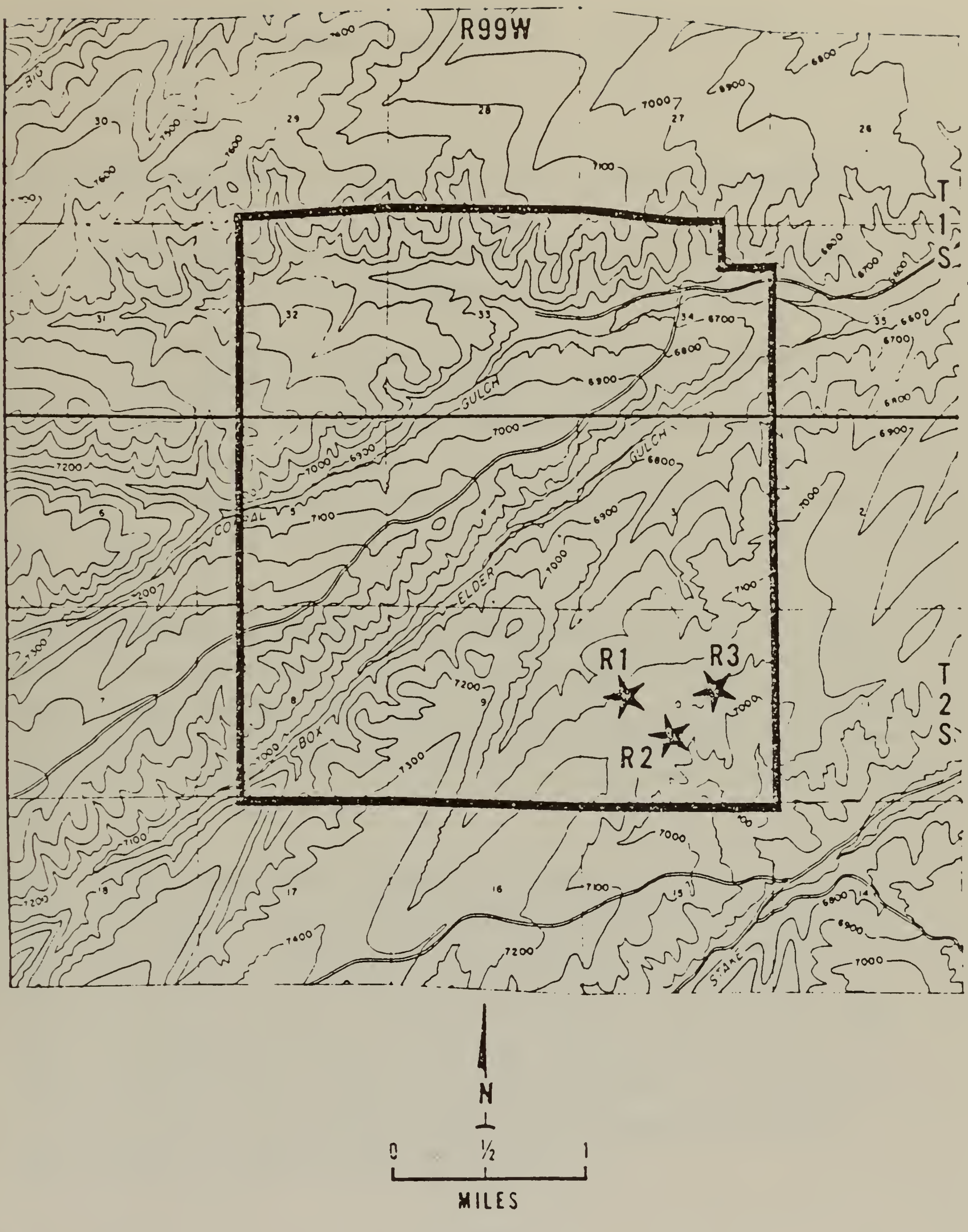

FIGURE 6.1

LOCATION OF REVEGETATION TEST PLOTS (R_1, R_2, AND R_3)

CHAPTER 1 - REVEGETATION EXPERIMENTS INITIATED IN 1975

I. OBJECTIVES

Revegetation experiments initiated in 1975 were designed to determine:

- Which species when sown in a composite mixture are best adapted to the physical and environmental conditions existing on the tract
- The effectiveness of several mulches in aiding establishment of the sown plant species and in reducing erosion
- The effects of fertilizer applied at different time periods on the sown plant species
- The effect of aspect on the establishment of the sown species.

II. METHODS

Native vegetation was scraped from each experimental plot site (R_1 and R_2) prior to substrate mixing. Topsoil (about the upper 6 inches of the soil) and the remaining subsoil were stockpiled separately. The underlying bedrock, consisting mostly of fractured calcareous sandstone, was broken to a minimum thickness of 24 inches. Subsoil and topsoil were replaced and graded for sowing.

At R_1 and R_2, each of the 16 treatments was applied at random to a 10 x 10 m plot and replicated in three complete blocks (Figure 6.2). Each plot was surrounded by a 3 m buffer zone. The total dimensions of the site are 55 x 165 m or 9,075 m^2 (0.91 ha or 2.24 acre per site). The site preparation process disturbed a perimeter around each site, bringing the total area of disturbance per site to 1.7 ha (4.3 acre) or 3.5 ha (8.6 acre) for two sites (R_1 and R_2) (Figure 6.2). Within each 10 x 10 m plot, four 1 x 1 m (3.3 ft x 3.3 ft) subplots were randomly established and permanently marked for subsequent data collection.

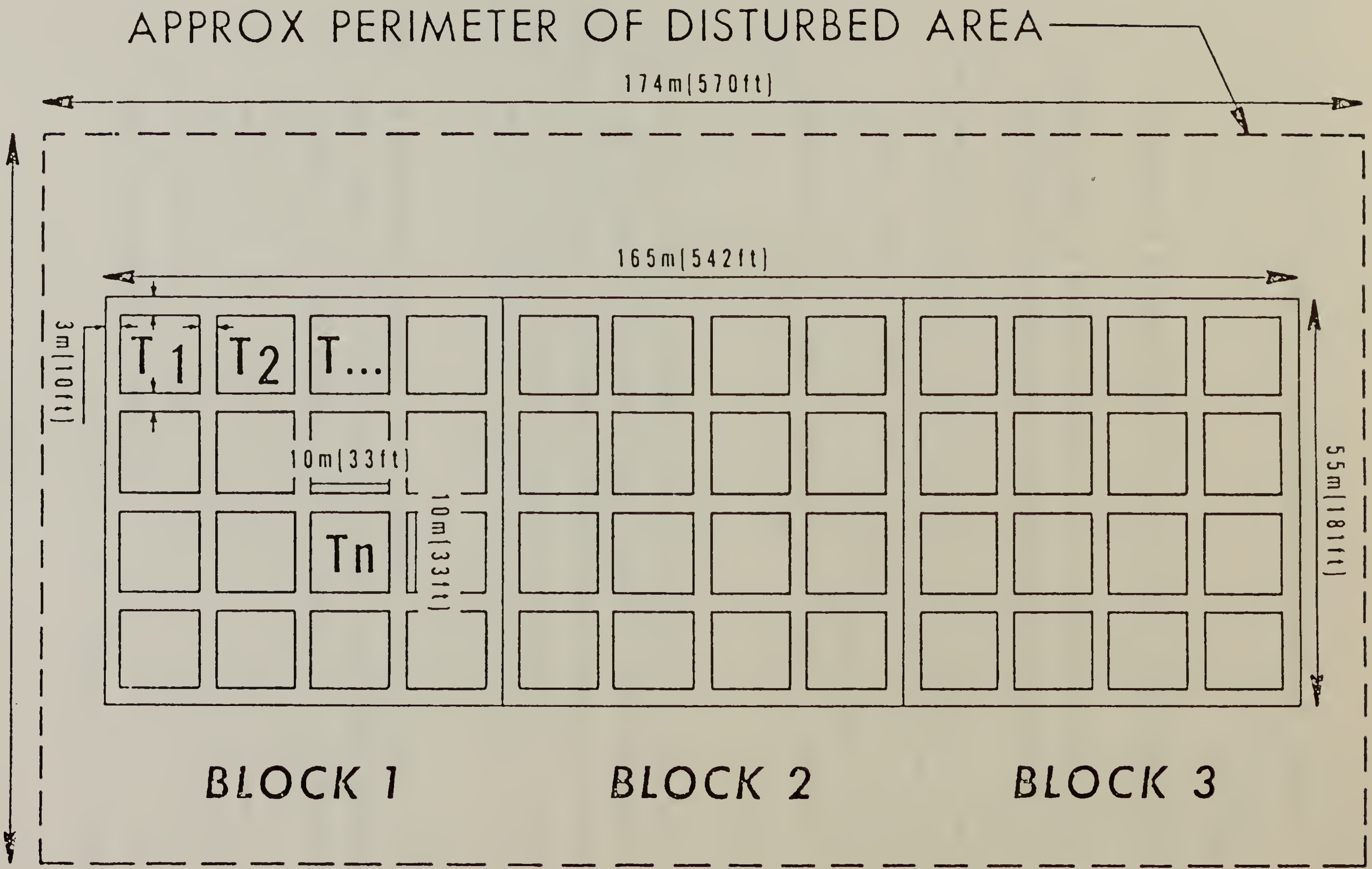

FIGURE 6.2

GENERALIZED PLOT LAYOUT FOR REVEGETATION PLOTS (R_1 & R_2) ON OIL SHALE LEASE TRACT C-a, RIO BLANCO COUNTY, COLORADO, 1975 - 1978. SIXTEEN TREATMENTS (T1-T16) ARE REPLICATED IN THREE COMPLETE BLOCKS. BLOCKS AND TREATMENT PLOTS WERE RANDOMLY SELECTED.

A composite mixture of grasses, forbs, and woody plants was drilled with a conventional grassland drill equipped with depth bands and a single-seed box and agitator. This drill placed the seeds in rows 5 to 7 inches apart. Approximately 11 lbs of pure live seed (PLS)/acre of grasses and non-grasses (forbs and woody plants) were sown in approximately equal proportions (Table 6.2).

For the 1975 test, a total of 16 treatments was applied with all possible combinations of the following variables:

Mulch Type and Application

- No mulch
- Hydromulch with wood fiber
- Straw mulch followed by crimping
- Straw mulch with netting

Fertilizer Application (10-5-5 applied at a rate of 160 lbs/acre)

- No fertilizer
- Fertilizer at time of sowing (fall)
- Fertilizer at the beginning of first full growing season (spring)
- Fertilizer at time of sowing and at the beginning of first full growing season.

Additional information concerning the details of the methodology used for these experiments is available in the RBOSP Progress Report 4 Summary (1975).

III. RESULTS

Data on emergence density, survival density, and percent cover were collected during the first growing season (1976) for the revegetation experiments initiated in 1975. Additional measurements of cover and measurements of above-ground biomass will be collected, as outlined in Table 6.3.

TABLE 6.2

PLANT SPECIES SUITABILITY AND RECOMMENDED SOWING RATES (LBS PLS/ACRE) FOR SPECIES UITILIZED IN REVEGETATION EXPERIMENTS ON OIL SHALE TRACT C-a, RIO BLANCO COUNTY, COLORADO

Species	Suitability Rating[a]	1975 Seeding Rates (lbs PLS/ac)	1976 Seeding Rates (lbs PLS/ac)
Grasses			
Luna pubescent wheatgrass (Agropyron trichophorum var. Luna)	2,4,6,8,9	1.1	1.8
Rosana western wheatgrass (Agropyron smithii var. Rosana)	4,5,8,9	1.3	1.9
Sodar streambank wheatgrass (Agropyron riparium var. Sodar)	3,5,8,9	1.4	1.3
Indian ricegrass (Oryzopsis hymenoides)	2,4,5,7,9	0.5	.4
C-43 Basin wild rye (Elymus cinereus var. C-43)	2,4,5,7,11	0.9	
Green needlegrass (Stipa viridula)	2,5,7	1.3	1.3
Manchar brome (Bromus inermis)	1.6,8		1.3
Forbs			
Lewis flax (Linum lewisii)	2,5	.4	.8
Lutana cicer milkvetch (Astragalus cicer var. Lutana)	6,11	.1	.7
Utah sweetvetch (Hedysarum utahensis)	2,5	.2	.3
Madrid yellow sweetclover (Melilotus officinalis var. Madrid)	2,4,5,9,11	.4	.6
Rocky Mountain penstemon (Penstemon strictus var. bandera)	3,5,9	.4	.4
Scarlet globemallow (Sphaeralcea coccinea)	3,5,9	.2	
Common daisy (Chrysanthemum leucanthemum)	3,5,9		.3

TABLE 6.2 (Continued)

Species	Suitability Rating[a]	1975 Seeding Rate (lbs PLS/acre)	1976 Seeding Rate (lbs PLS/acre)
Shrubs			
Big sagebrush (Artemisia tridentata)	2,5,9,10,11	.1	
Little rabbitbrush (Chrysothamnus viscidiflorus)	2,4,5,9,11	.1	
Bitterbrush (Purshia tridentata)	1,5,9,10,11	.5	.8
Mountain mahogany (Cercocarpus montanus)	1,5,10	.3	.8
Fourwing saltbush (Artiplex canescens)	1 (seeds), 3,4,5,9	.5	.7
Winterfat (Eurotia lanata)	1,5,10	.3	.4
Rubber rabbitbrush (Chrysothamnus nauseosus)	3,5,9,10,11	.3	.4
Squaw bush (Rhus trilobata)	2,4,5,9,10,11	.2	
Serviceberry (Amelanchier alnifolia)	2,5,10,11		.6
Trees			
Utah juniper (Juniperus osteosperma)	3,5,9,10,11	0.1	
Pinyon pine (Pinus edulis)	3,5,9,11	0.1	.2
	TOTAL	10.7	15.0

[a]Suitability ratings are:

1 highly palatable
2 moderately palatable
3 unpalatable
4 soil stabilizer
5 native to Colorado[b]
6 introduced species
7 bunch grass
8 sod grass
9 drought resistant
10 browse
11 cover for game

[b]Underlining indicates species observed on site as part of the environmental baseline studies.

TABLE 6.3

PLANT RESPONSE PARAMETERS MEASURED IN REVEGETATION EXPERIMENTS ON OIL SHALE TRACT C-a, RIO BLANCO COUNTY, COLORADO, 1976 - 1978

Parameter	Time of Measurement	Taxa Involved
Number of emerged seedlings per plot	first spring following fall planting, i.e., beginning of first growing season	each planted species
Number of surviving seedlings	end of first growing season	each planted species
Above-ground biomass (dry wt.)	end of third growing season	total seeded species, total alien species, individual seeded species contributing bulk of biomass
Percent cover	end of each growing season	each species

Results of an analysis of variance on emergence, survival, and cover data indicated that significant differences occurred among species and among treatments. The first year density data indicated significant differences among mulch treatments. Generally, the straw mulches had better seedling establishment and survival than the no mulch or hydromulch treatments. The results of the effect of fertilizer application at different time periods were less conclusive. Further measurements of percent cover and biomass should provide more valid tests of the effects of fertilizer.

Of particular interest was the success obtained by seeding shrubs directly. Winterfat, rabbitbrush, and saltbush and, to a lesser extent, bitterbrush and mountain mahogany were common species on both the north and south slopes. Winterfat set seed during the first growing season and rabbitbrush and saltbush frequently obtained heights of 12 to 14 inches. These results indicated that wildlife habitat similar to that presently existing on Tract C-a can be reestablished.

Additional information concerning the results of the first year of the 1975 experiments is presented in the RBOSP Progress Report 9 (1977).

CHAPTER 2 - REVEGETATION EXPERIMENTS INITIATED IN 1976

I. OBJECTIVES

Revegetation experiments initiated in 1976 were designed to determine:

- If the simulated artificial soil profile can inhibit upward capillary migration of salts from TOSCO II processed shale
- Which plant species (sown in a composite mixture on the simulated artificial soil profile) are best adapted to the environmental conditions existing on a south exposure on Tract C-a
- Which mulches when applied to the simulated artificial soil profile are effective in aiding establishment and survival of plant species and in reducing erosion
- Growth and survival of native shrubs that are sown directly or planted as tubelings on the simulated artificial soil profile.

II. METHODS

The 1976 revegetation experiments were designed to simulate the artificial soil profile which will cover the processed shale disposal pile (RBOSP Detailed Development Plan, 1977). Preliminary designs of a typical disposal pile have the following strata, from top to bottom:

0.3 - 0.6 m (1/2 - 1 ft) of soil material	Artificial soil profile
0.9 - 1.5 m (3 - 5 ft) of raw shale ore (0 - 8 inches size)	
1.5 m (5 ft) of 95% compacted processed oil shale	
0 to several hundred meters of 80% compacted processed oil shale	
1.5 m (5 ft) of 95% compacted processed oil shale	

The values for soil material and the layer of raw shale ore represent minimum ranges in depth for the artificial soil profile.

This artificial soil profile should provide an adequate quantity and quality of rooting medium to support plant cover and minimize direct root contact with the processed shale. The larger pore size of the crushed raw shale should reduce capillary movement of salts from the processed shale into the rooting zone. In addition, the chemical characteristics of raw shale ore (C. McKell, Utah State University, personal communication, 1977) are not expected to inhibit successful plant establishment.

The simulated artificial soil profile was prepared by separately stockpiling topsoil (6 inches), subsoil (12 inches), and excavated sandstone (12 inches). An additional 36 inches of rock and soil material was excavated from the revegetation site and stockpiled. A plastic sheet was placed into a prepared area 5.5 ft deep to reduce the possibility of contamination to ground water and to facilitate collection of any leachate for analysis. Perforated plastic pipe was placed in three locations for collection of leachate: 1) at the top of the compacted shale, 2) beneath the compacted shale, and 3) beneath the sandstone material on the control side of the experimental plot. Due to the limited availability of TOSCO II processed shale, 20 inches of processed shale was placed on top of the plastic sheet. The processed shale was compacted to prevent penetration or leaching and to simulate the 5 ft surface layer of the compacted processed shale of the proposed disposal pile configuration. The control plot was underlain by approximately 20 inches of sandstone which had been excavated from the revegetation site and which had previously been stockpiled. After the processed shale was compacted, 3 ft of overburden (12 x 0 inch size) was bulldozed over the processed shale and the excavated sandstone of the control plot. The topsoil and subsoil were replaced in proper sequence.

The 1976 revegetation site was a 53 x 53 m (174 x 174 ft) area (0.3 ha or 0.70 acre) (Figure 6.3). An approximate 23 m (75 ft) wide boundary area surrounding the revegetation site was disturbed by operation of machinery, removal and stockpiling of vegetation, and temporary stockpiling of soil material. Thus a total of 1.0 ha (2.41 acres) was disturbed by the 1976 experiments.

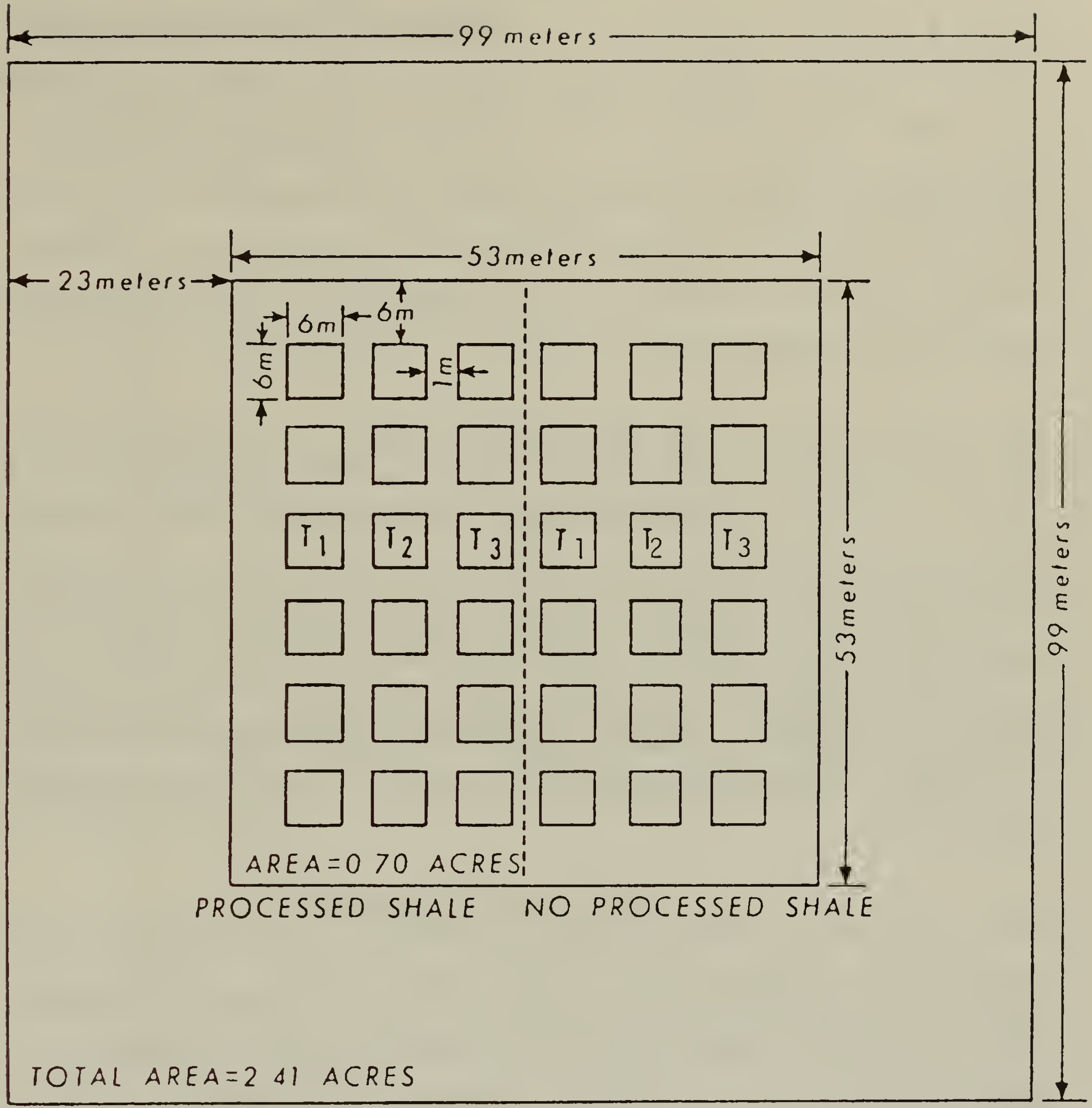

FIGURE 6.3

GENERALIZED PLOT LAYOUT FOR REVEGETATION PLOT (R_3) ON OIL SHALE TRACT C-a, RIO BLANCO COUNTY, COLORADO (INITIATED IN 1976). APPLICATIONS OF THREE MULCH TREATMENTS (T_{1-3}) WERE APPLIED TO 2 CONDITIONS FOR A TOTAL OF SIX TREATMENTS. THESE TREATMENTS WERE REPLICATED SIX TIMES.

At the site, each 6 x 6 m plot received one treatment and the six treatments (3 mulch and 2 shale-no shale conditions) were applied six times to a total of 36 plots (Figure 6.3). Each plot is surrounded by a 1 m buffer zone, except that a 5 to 6 m buffer zone exists along the outermost perimeter of the treatment plots to reduce microclimatic effects and a 3 m buffer occurs in the center of the plot at the interface of the processed shale and control area. Within each 6 x 6 m treatment plot, a minimum of three 1.0 x 0.5 m subplots will be randomly established and permanently marked for subsequent data collection.

Grass, forb, and shrub seed was sown as a composite mixture (Table 6.2) after the simulated artificial soil profile had been prepared. For the 1976 test, 15.0 lb PLS/acre were sown, with non-grasses (forbs and woody plants) in slight excess of the grasses (Table 6.2). Seed was drilled using a conventional grassland drill equipped with depth bands and a single-seed box and agitator. Rice hulls were added to the seed mixture as a "filler substance" to increase the bulk of seed in the seed box. Depth bands insured that seed was not drilled deeper than 2 cm (0.5 to 0.75 inches). Drilling resulted in a spacing of 5 to 7 inches between planting rows.

Direct seeding of a composite seeding mixture will be compared to plantings of tubelings, a popular type of containerized seedling. Tubelings are being grown by the USDA Shrub Science Laboratory from the same seed lots that were used for direct seeding. Five shrub species (excluding _Amelanchier alnifolia_) and pinyon pine will be utilized for the tubeling treatment. Tubeling size will be 18 cubic inches (2 inches x 1.5 inches x 6 inches). The tubelings will be planted by hand in each treatment plot in early or mid-June at a rate of 18 tubelings/plot (1800 tubelings/acre); three tubelings of each of the six species will be used.

For the 1976 tests, six treatments consisting of all possible combinations of the following variables were applied:

Simulated Artificial Soil Profile

- Simulated artificial soil profile underlain by excavated sandstone ("control")
- Simulated artificial soil profile underlain by TOSCO II processed shale.

Mulch Type and Application

- No mulch
- Hydromulch with wood fiber (0.75 tons/acre)
- Native hay followed by crimping (2 tons/acre).

The following plant response parameters will be measured for each treatment: 1) number of emerged seedlings per plot, 2) number of surviving seedlings per plot, and 3) percent cover. Table 6.3 gives the season of measurement for each parameter and the taxa involved. Additional information concerning the experiments initiated in 1976 are presented in the RBOSP Progress Report 9 (1977).

SUMMARY AND CONCLUSION

The revegetation experiments outlined above will provide information which can be used to supplement, if necessary, the revegetation plans presented in the RBOSP Detailed Development Plan (1977). The results are expected to be used to further refine the selection of specific seed mixtures for different site conditions and of the most effective mulches, fertilizer schedule, and shrub establishment techniques. In addition, the trials will indicate how well vegetation can be established and maintained without supplemental irrigation. Most important, the use of TOSCO II processed shale in the experiments initiated in 1976 will test the feasibility of using a crushed rock layer to reduce upward migration of salt into the plant rooting zone.

The third planting will be done in the fall of 1977. The methods and treatments of this experiment will be submitted to the AOSO for approval prior to

planting activities. As additional measurements are made during the next two growing seasons, the results and interpretations will be reported periodically to the AOSO. Final recommendations for the RBOSP revegetation plan will be based on the results of these experiments and will be made upon completion of the tests in 1978.

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APPENDIX

APPENDIX

APPENDIX

LISTING OF INFORMATION

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TERRESTRIAL ECOLOGY SECTION

OF

RBOSP PROGRESS REPORT 10 (1977)

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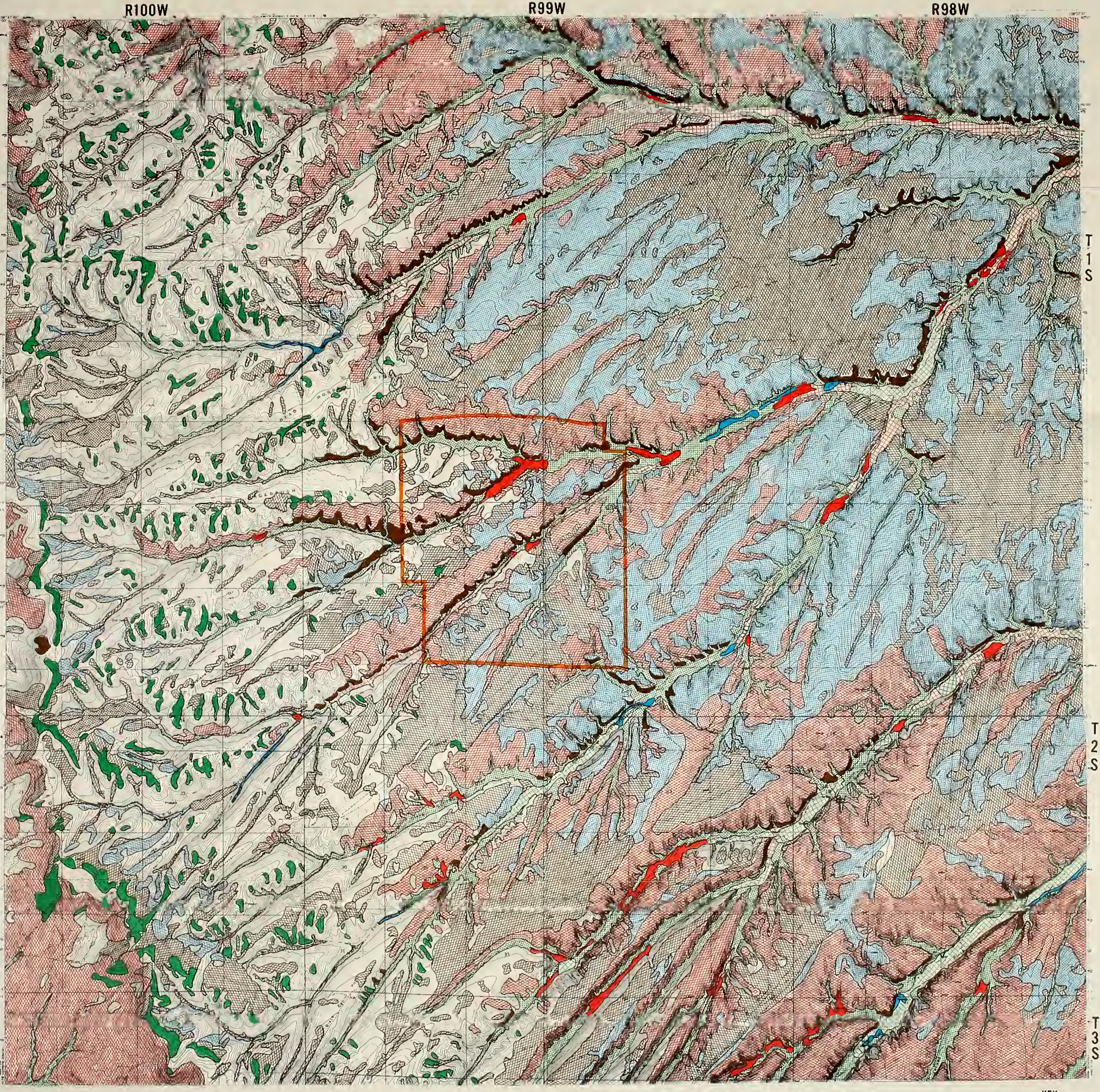

TERRESTRIAL ECOLOGICAL INVESTIGATIONS

RIO BLANCO OIL SHALE PROJECT

TRACT C-a

VEGETATION TYPES

KEY

1	2
3	4

LOCATION AND EXTENT OF VEGETATION TYPES ON TRACT C-a AND VICINITY

- DOUGLAS FIR
- ASPEN
- MIXED BRUSH
- PINYON - JUNIPER
- PINYON - JUNIPER MIXED BRUSH
- PINYON - JUNIPER SAGEBRUSH
- UPLAND SAGEBRUSH
- BOTTOMLAND SAGEBRUSH
- RABBITBRUSH
- GREASEWOOD
- SHADSCALE
- RIPARIAN
- BALD
- AGRICULTURE

Form 1279-3
(June 1984)

BORROWER'S

DATE LOANED	BORROW

USDI - BLM